MineTwin Underground Documentation

2026-07-10

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Introduction

Purpose of the document

This document describes the tool for planning and simulation of mining operations. The document is designed for users of MineTwin as a source of knowledge about the tool.

System description

MineTwin Underground allows one to perform scheduling and simulation of mining operations that occur in underground mines.

MineTwin Underground consists of the following modules:

1. Data input module (editor)
2. Integration module (importing data from external systems)
3. Planning module (scheduler)
4. Simulation module (simulation model)

The data input module allows you to create and edit scenarios in the MineTwin Underground user interface and save the result in .xlsx format. The scenario file can also be edited in MS Excel. The integration module allows you to import data from other systems about the mine's transportation system, the location and characteristics of the mine workings, equipment maintenance breaks, and more. MineTwin Underground supports the import of data in .xlsx, .txt, and .dxf formats. The simulation of the mine development process in MineTwin is based on the sequential operation of the planning and simulation modules:

1. The operation of equipment is planned for one shift, taking into account the target indicators
2. The operation of equipment and transport is modeled based on the plan drawn up by the planner for this shift. The next planning is performed using the results of modeling this shift and target values for the period.

System requirements

MineTwin requires 32- or 64-bit Windows 7 or higher.

Microsoft Office Excel 2007 or higher must be installed on the PC.

1. Edit scenario

1.1. Preparing the input file

A MineTwin Underground scenario is defined in an Excel file containing all required input data.

Creating a scenario in MineTwin Underground is possible in two ways:

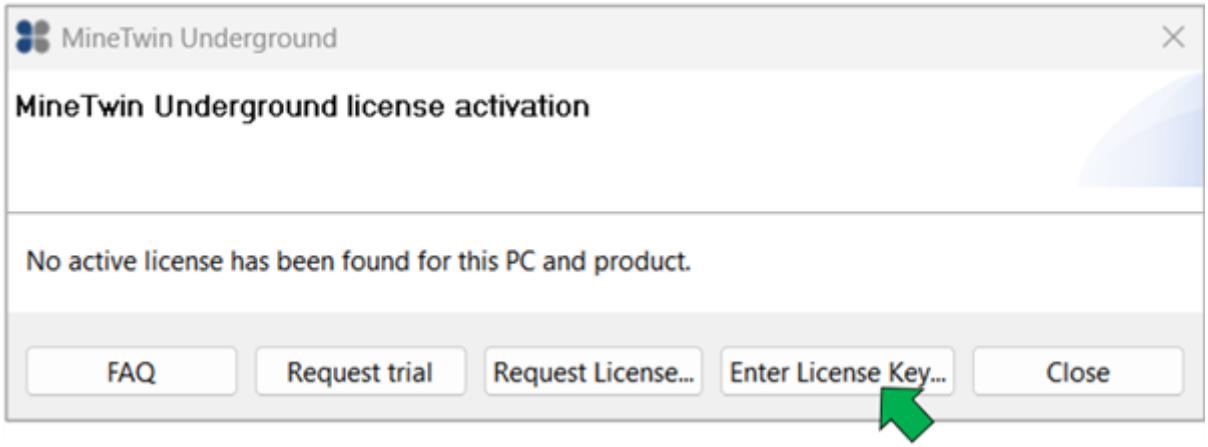
1. In the application interface – all source data, such as haul road network elements, equipment types and units, equipment and haul truck schedules, assignment of equipment and trucks to mining areas, etc., are added/deleted manually directly in the application. The enterprise's haul road network topology can be added to a scenario by importing road centerlines in .dxf format.
2. By importing a template with source data – when creating a new scenario, the application allows the user to import the core data from a pre-filled Excel template.

1.2. Launching the application, loading the editing mode

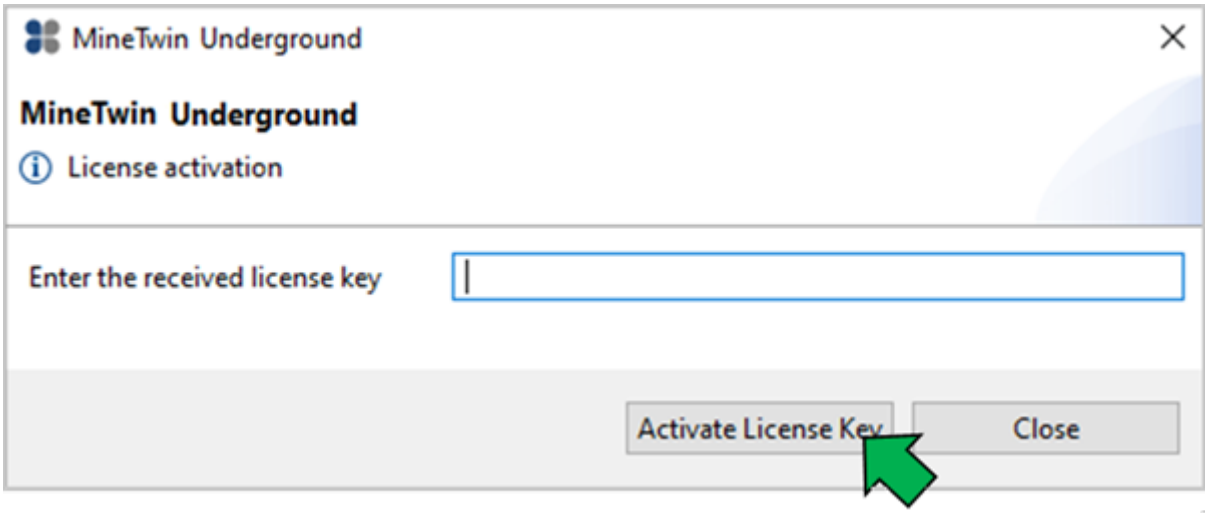
To install the MineTwin Underground application on your computer, you need to unzip the "***MineTwin***" folder and save it on your local computer.

1. MineTwin Underground is launched from the unzipped folder by launching the ***MineTwin.exe*** application ( ).

2. If MineTwin is launched on a PC for the first time, the system will inform you that the license was not found.

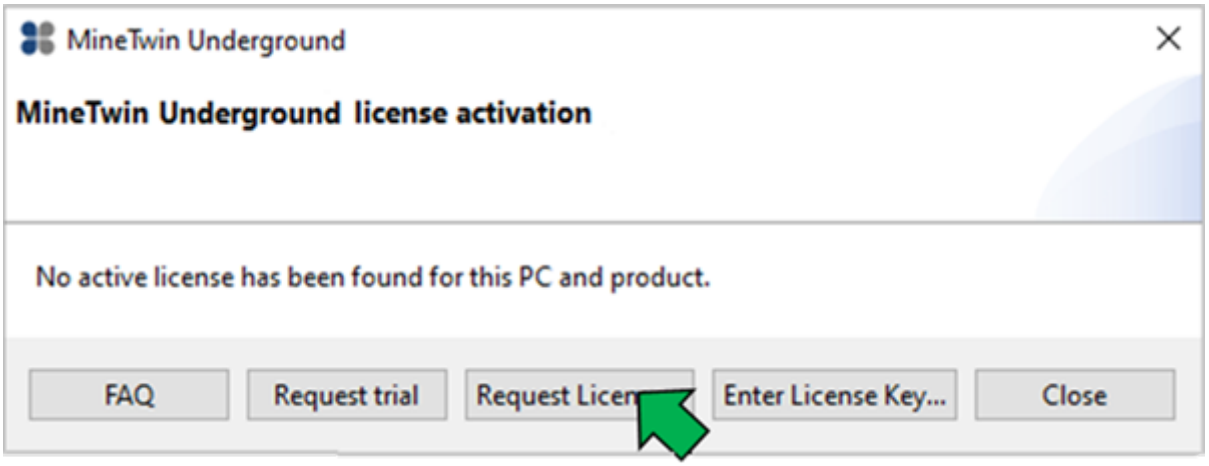


3. After clicking the license key entry button, a window will open where you can insert the 16-digit license key and click the key activation button.

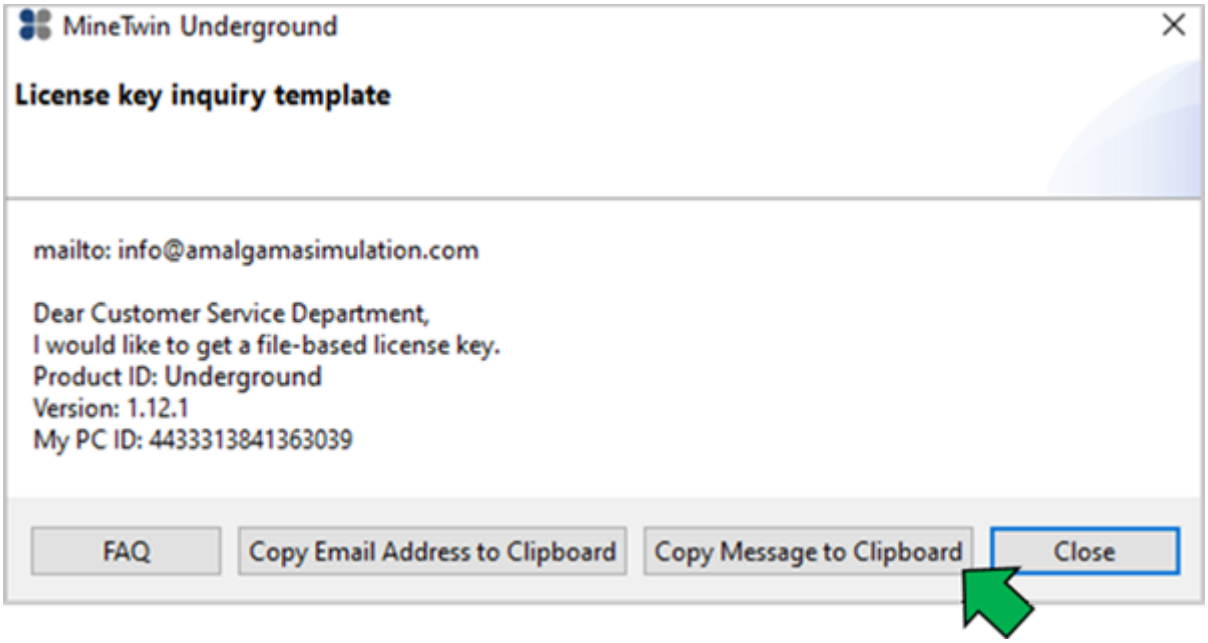


If the key is correct and is not activated on another PC, MineTwin Underground will be launched.

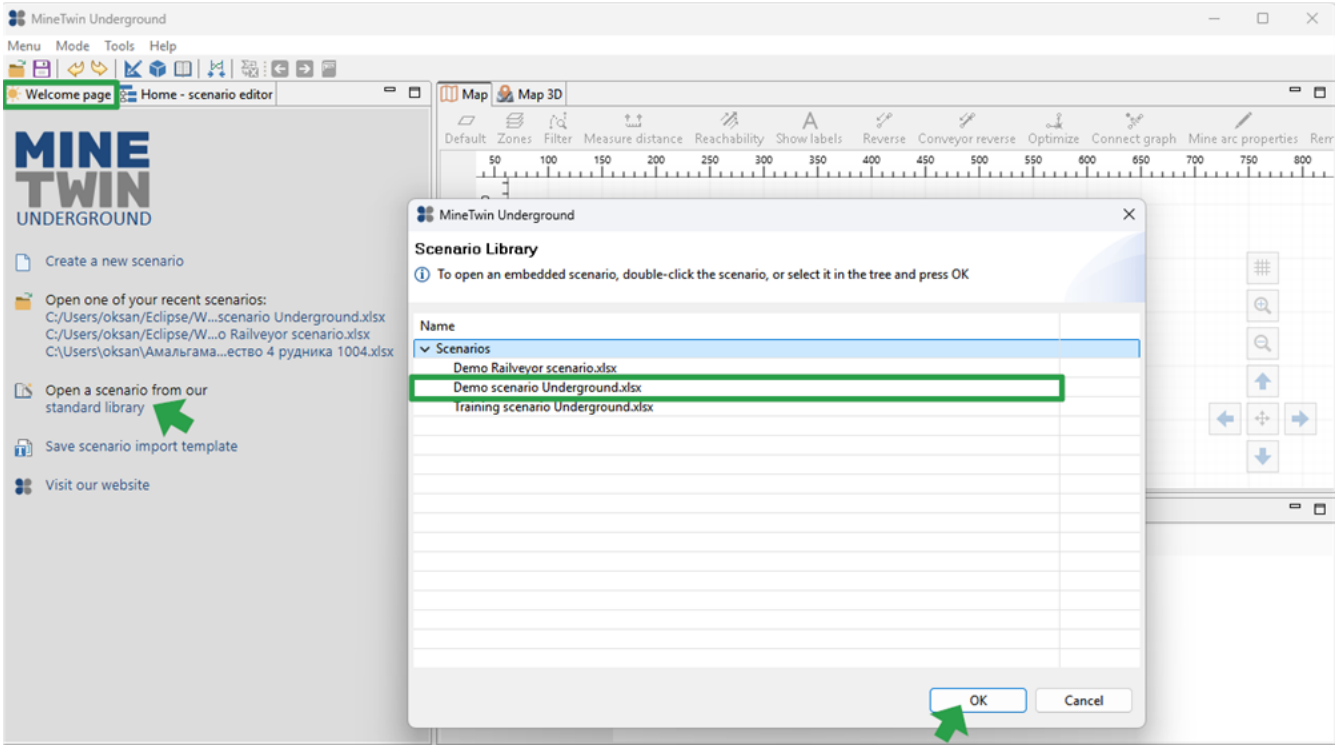
4. If there is no commercial license, the user can use a trial license that is valid for 30 days by clicking on the button Request trial.
5. If there is no internet access when you open the app, you must connect to the internet or contact the developer for help by providing the unique PC ID that appears when you click on the license request button.



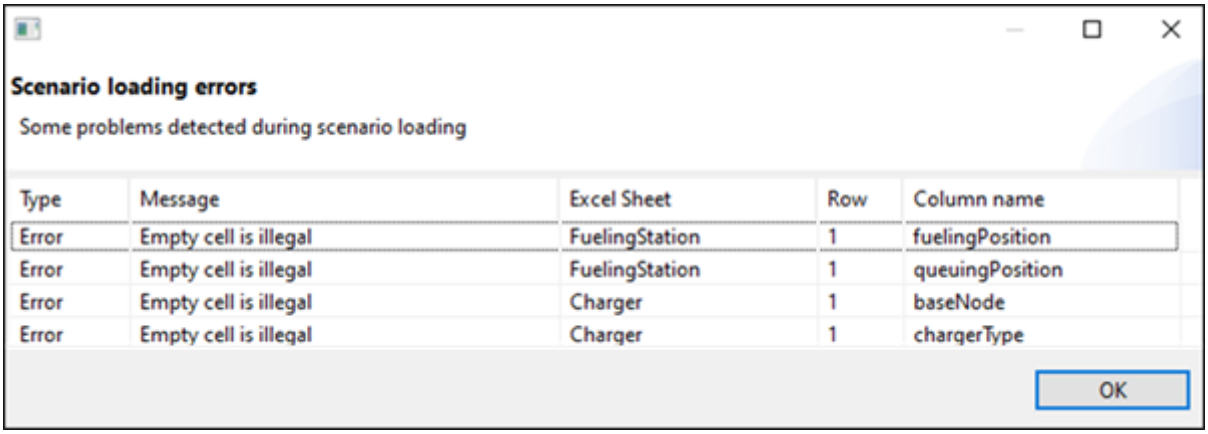
6. Copy the message text by clicking the button Copy Message to Clipboard and send it to the MineTwin technical support.



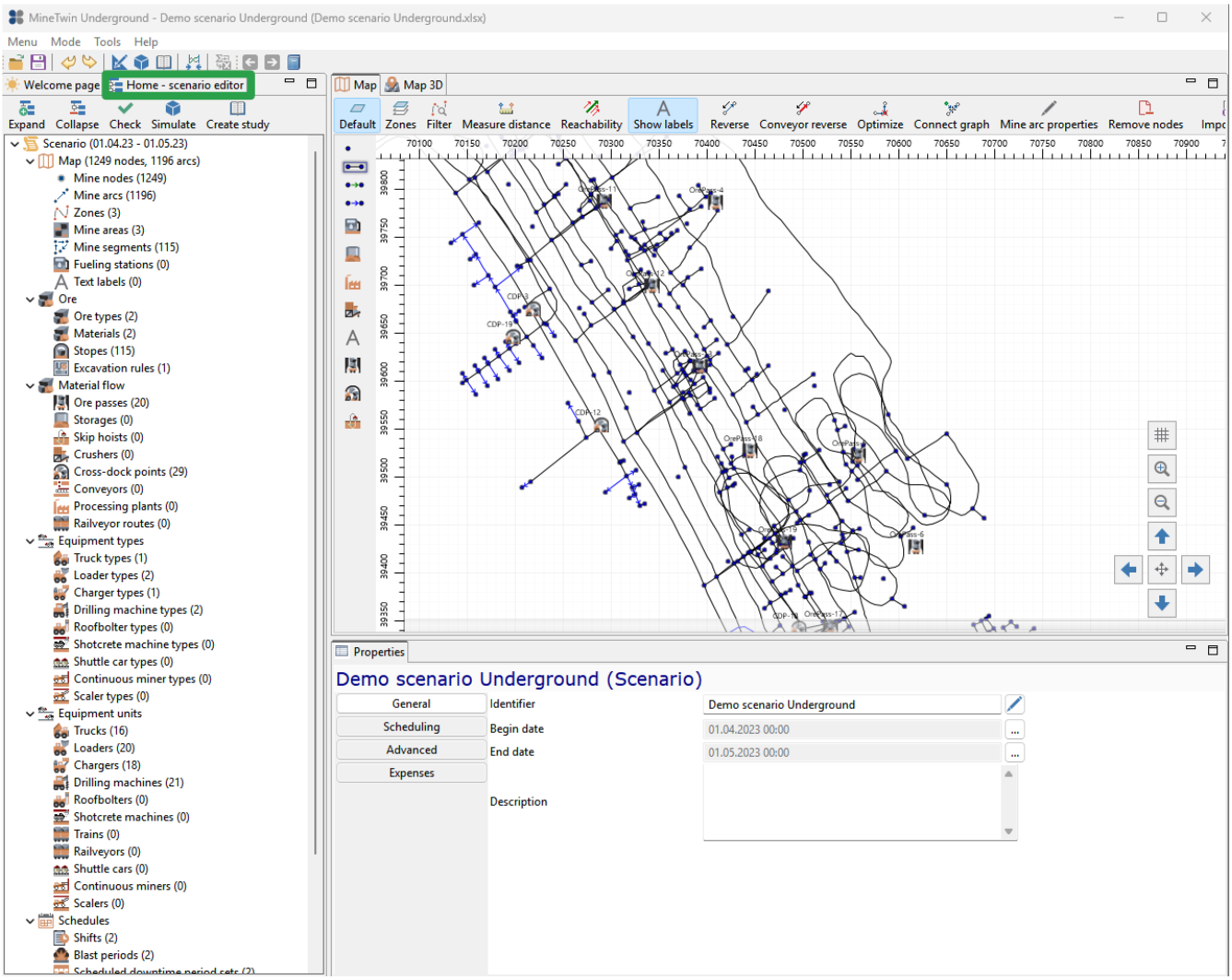
7. After launching MineTwin Underground the application's working window will open. On the left side of the window, on the **Welcome page** tab, the following functions are located:
    - **Create a new scenario** – this function creates a new scenario file that requires manual data entry and/or data import
    - **Open one of your resent scenarios** – this function displays a list of recently opened scenarios on the panel for quick switching between them
    - **Open a scenario from our standart library** – this function opens a window with a set of demonstration scenarios
    - **Save scenario import template** – clicking this function downloads an Excel file of the established format to your PC, which is used to fill in the core data and subsequently create a scenario by importing it.
    - **Visit our website** – this function redirects to the website of Amalgama LLC.



If the scenario opened contains errors, a window with a list of errors will open, indicating the name of the Excel file sheet and the number of columns and lines that contain errors. The user can open the list in a separate file and sequentially correct the errors in the downloaded Excel file or download the scenario file with errors and then fix them in the system.



After opening the scenario in the MineTwin Underground interface, the scenario editing mode window will open, the appearance of which is shown in the figure.



The editing mode contains several windows, which sizes can be changed by selecting the side of the window and holding down the left mouse button. Any window can be moved from one part of the interface to another by clicking on the required window with the left mouse button and holding it while moving.

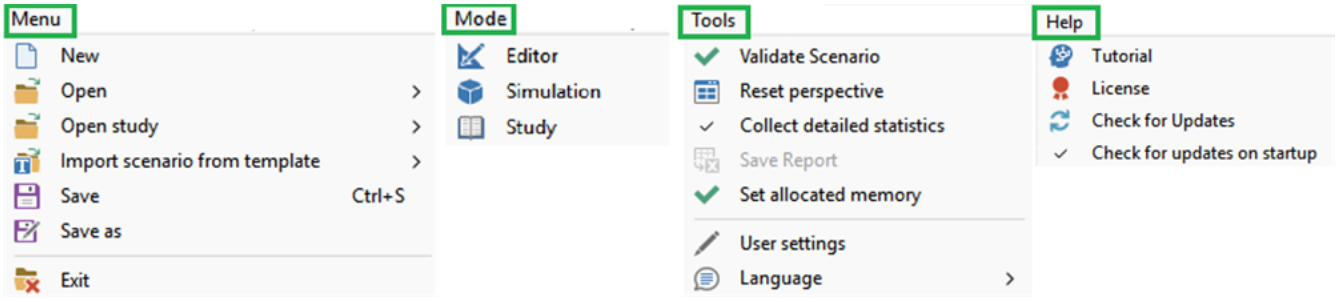
To open the selected window to full screen, you need to double-click on it. To return to normal mode, double-click again or use the function *Reset perspective*.

1.3. Elements of the scenario editor

The scenario editor allows you to create, review, edit and save scenarios.

1.3.1. Tools

There is a toolbar at the top of the editing module.



The **Menu** group contains the following functions:

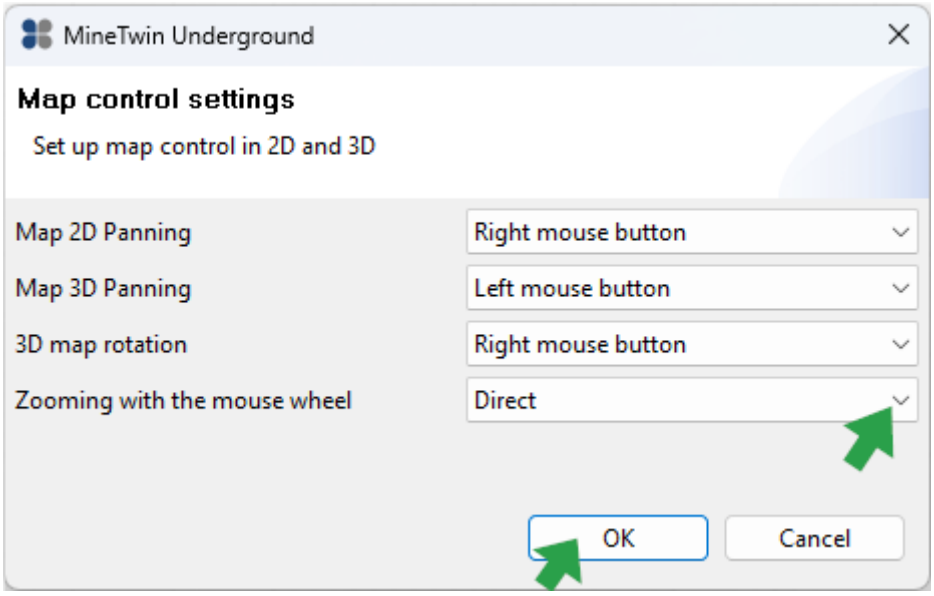
- Create a new scenario ( )
- Open scenario ( )
- Open study ( )
- Import scenario from template ( ) – this function creates a new scenario by importing the filled-in source data template
- Save scenario ( )
- Save As Copy ( )
- Exit ( ).

The **Mode** group is used to switch between the modes:

- Simulation ( )
- Editor ( )
- Study ( )

The **Tools** group contains the following functions:

- Validate scenario after its creation/editing ( )
- Collect detailed statistics ( ) — the ability to view the status of all equipment units at any moment in time
- Save Report ( )
- Set allocated memory ( ) - the function allows you to set the amount of RAM used during simulation
- User settings ( ). The user can choose the map panning/rotation method that suits them best in 2D and 3D modes



- Language switch (Russian and English are available)

The **Help** group contains:

- Link to the Tutorial
- License information, including PC ID that is needed to renew the license
- Check for Updates — manual check for updates
- Check for updates on startup — enable this option to have the software automatically check for updates each time it starts.

If it is necessary to undo/redo a canceled action, use the buttons .

The buttons duplicate the mode switching options available in the **Mode** group.

The button synchronizes graphs in the simulation mode.

The button allows the user to upload simulation results to an Excel file (general statistics, costs, equipment performance indicators, etc).

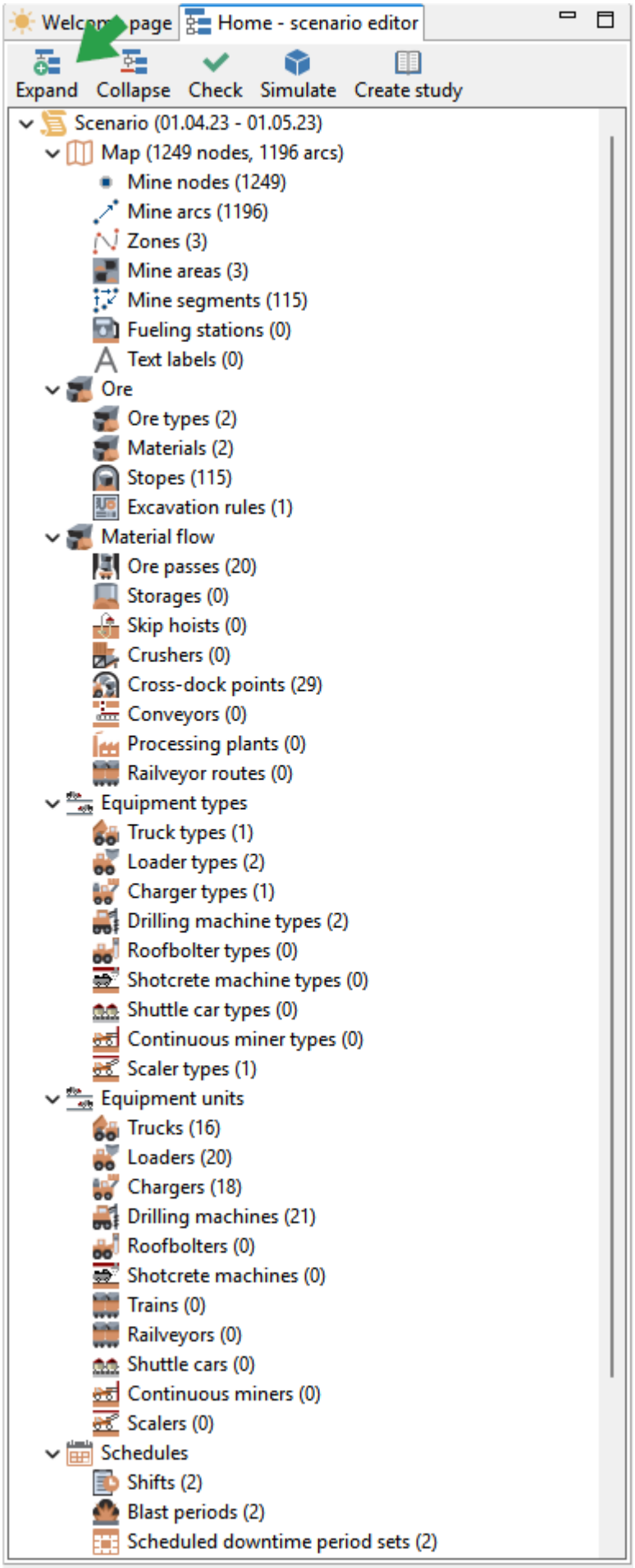
The buttons provide access to previously viewed directories and objects.

The button searches any scenario element by its name.

1.3.2. Model tree

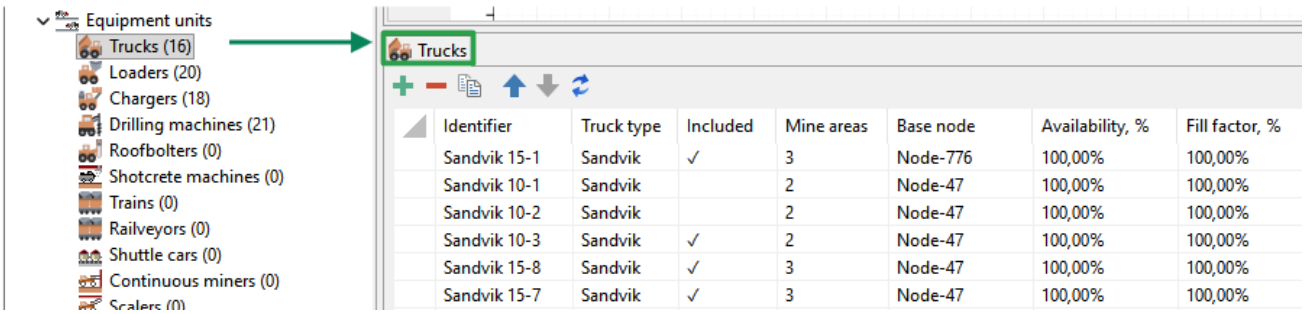
All scenario objects and entities data (parameters of stopes, dump areas, equipment units, equipment operation schedules, etc.) are displayed in the form of a tree and are grouped by types. For each type of object/entity, the number of units of the object/entity is shown.

Blocks of the model tree can be expanded/minimized for easy viewing.


Welcome page
Home - scenario editor
Expand
Collapse
Check
Simulate
Create study
Scenario (01.04.23 - 01.05.23)
Map (1249 nodes, 1196 arcs)
Mine nodes (1249)
Mine arcs (1196)
Zones (3)
Mine areas (3)
Mine segments (115)
Fueling stations (0)
Text labels (0)
Ore
Ore types (2)
Materials (2)
Stopes (115)
Excavation rules (1)
Material flow
Ore passes (20)
Storages (0)
Skip hoists (0)
Crushers (0)
Cross-dock points (29)
Conveyors (0)
Processing plants (0)
Railveyor routes (0)
Equipment types
Truck types (1)
Loader types (2)
Charger types (1)
Drilling machine types (2)
Roofbolter types (0)
Shotcrete machine types (0)
Shuttle car types (0)
Continuous miner types (0)
Scaler types (1)
Equipment units
Trucks (16)
Loaders (20)
Chargers (18)
Drilling machines (21)
Roofbolters (0)
Shotcrete machines (0)
Trains (0)
Railveyors (0)
Shuttle cars (0)
Continuous miners (0)
Scalers (0)
Schedules
Shifts (2)
Blast periods (2)
Scheduled downtime period sets (2)

1.3.3. Objects

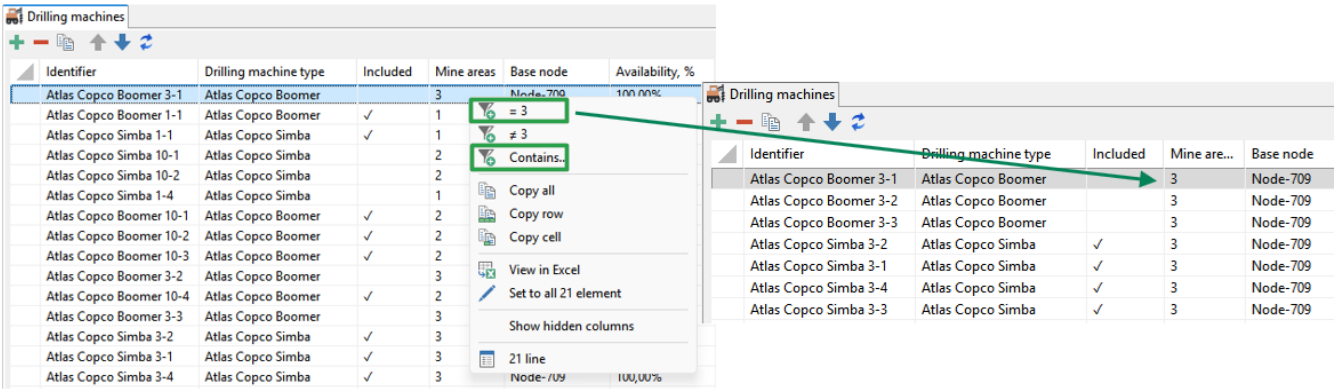
The **Objects** window displays a list of all units of objects/entities of the type selected in the object tree, for example, a list of all loaders, stopes, etc.



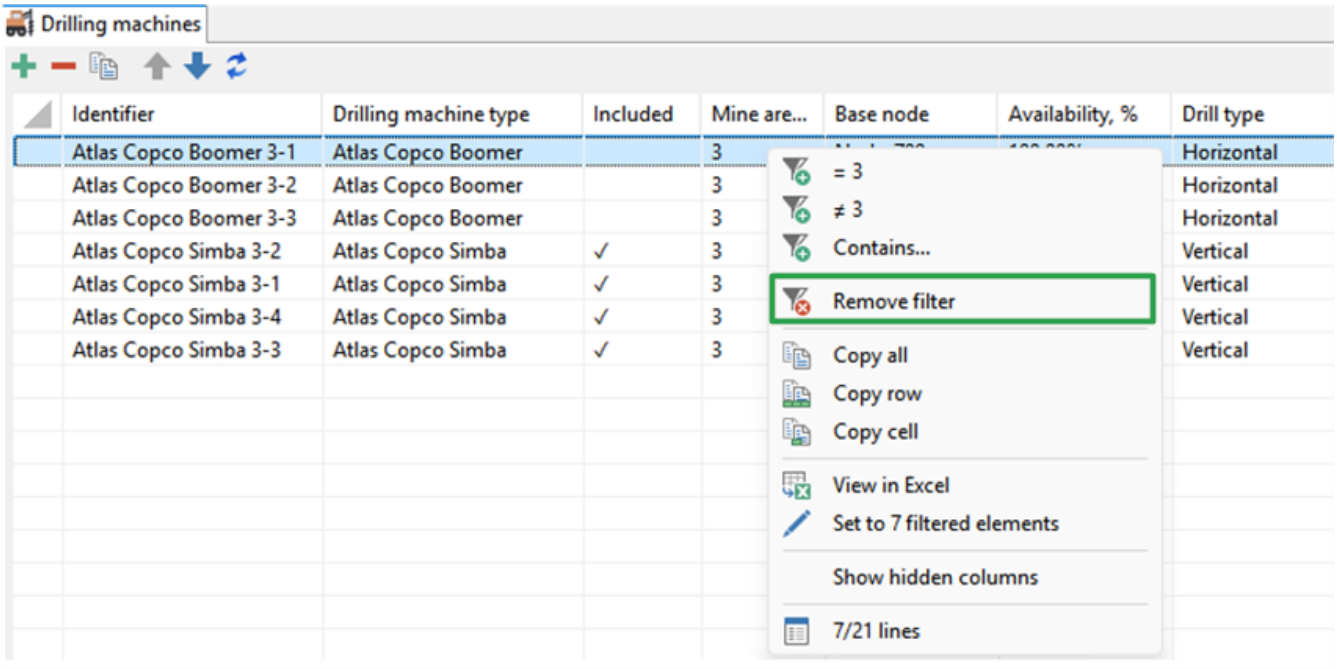
At the top of the **Objects** window, there is a toolbar with functions for adding, deleting, copying objects, moving objects up or down and refreshing values.

When you hover the mouse over the icon, the tooltip for this button will be displayed.

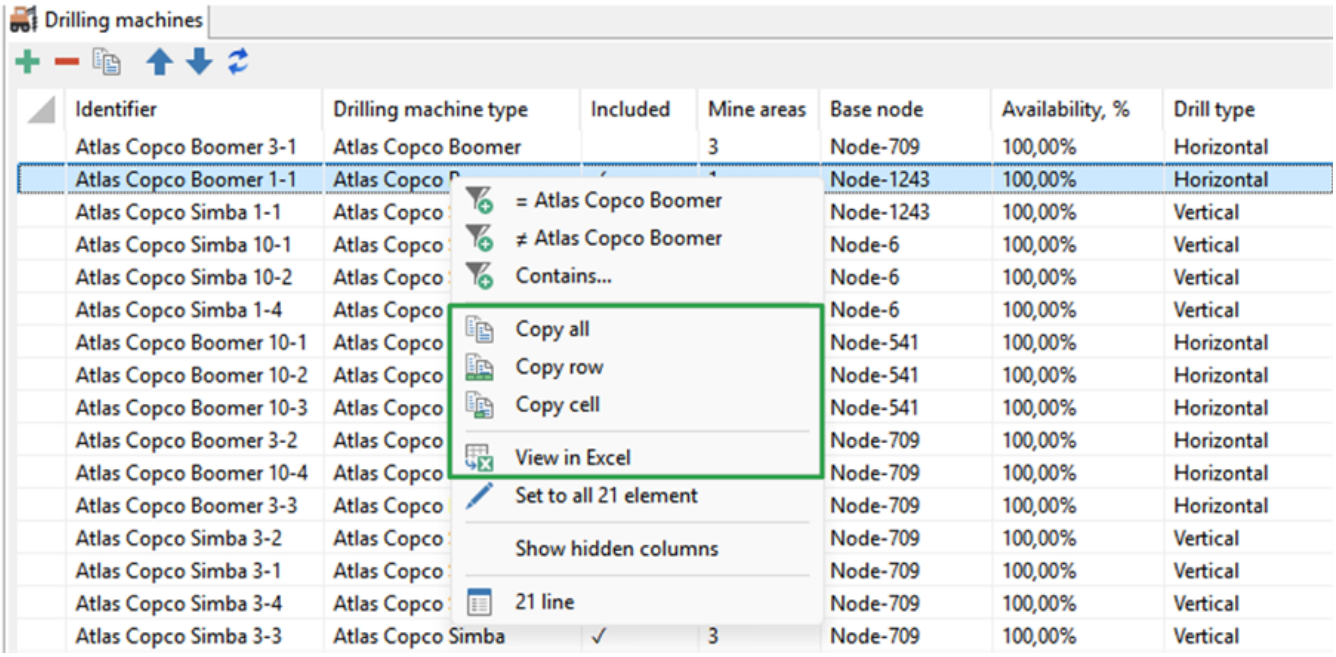
The data table supports sorting for all columns as well as filtering. To apply a filter, right-click a row in the desired column and set the required filter in the pop-up window.



To remove the filter, use the *Remove filter* button in the pop-up window.



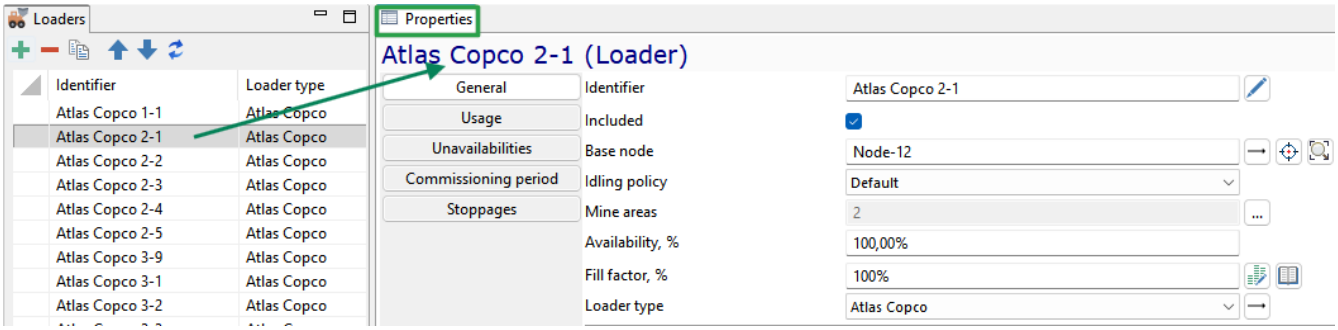
The contents of the entire table, selected rows, or individual cells can be copied or exported to Excel for further analysis.



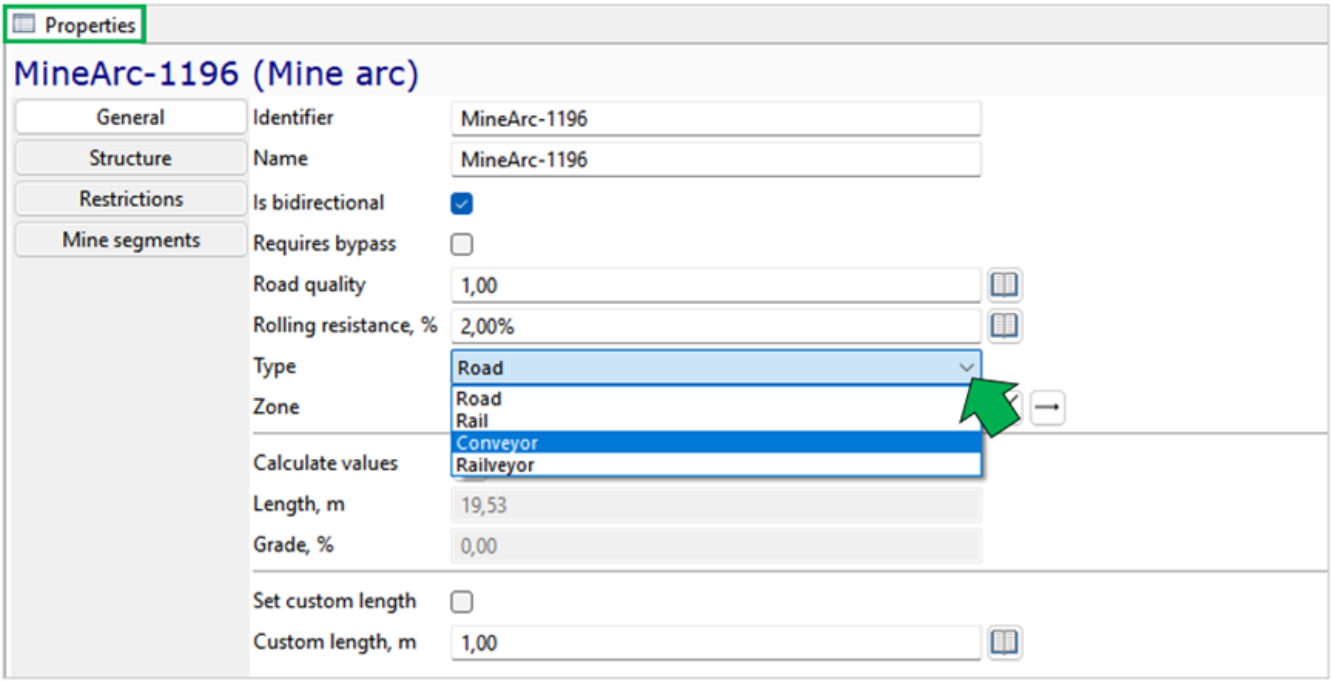
Most columns in the table are editable. To edit the value in a single cell, left-click it and make the necessary change. To edit all values in a column, use the *Set to all items button* — for example, to set the same explosives warehouse for all charging machines. You can also filter the rows (for example, by equipment type) and assign a value in the column only to the filtered cells — for instance, to specify the same work area for all trucks of a certain type.

1.3.4. Properties

The **Properties** window displays and allows editing of the properties of the object (entity) selected in the object list. To edit an object's properties, select the object in the list and switch to the **Properties** window.

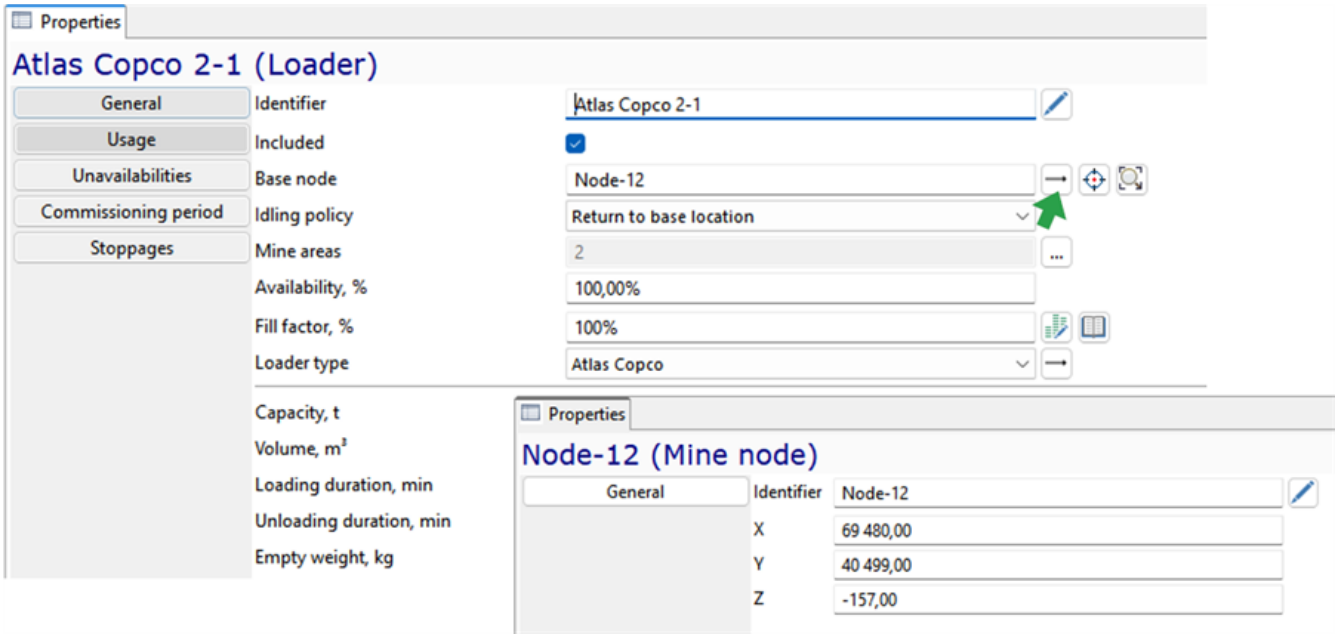


To change the parameters, the values of which are limited by the enumeration, the required value is selected from the drop-down list and removed by clicking on the cross to the right of the field.

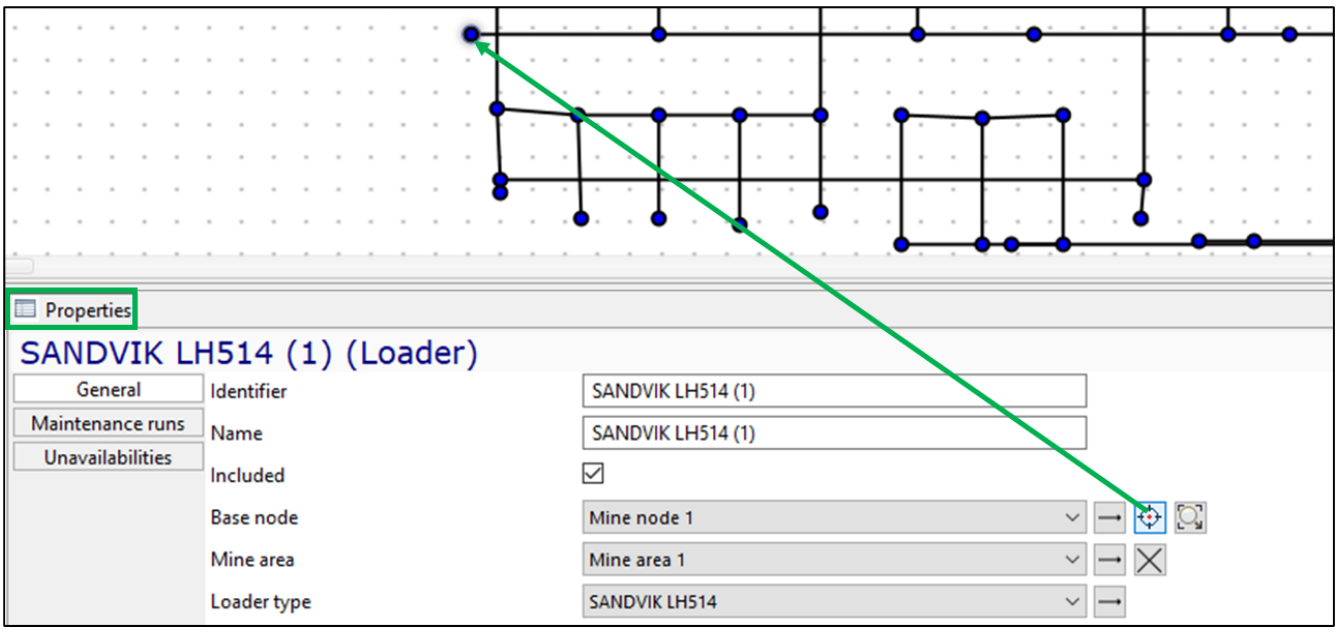


To update the data, use the button .

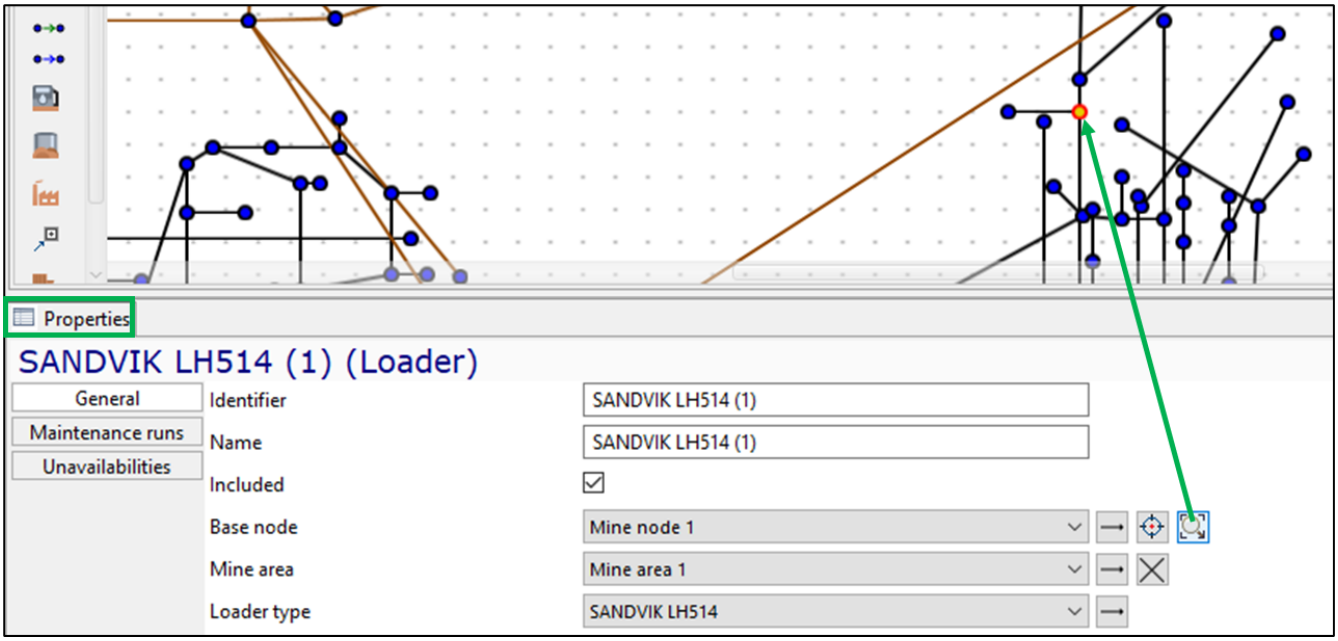
From the properties of the object unit, you can go to the properties of related objects, for example, from the properties of the equipment unit to the properties of the type of this equipment unit or the properties of its base node. To do this, click on the arrow to the right of the field.



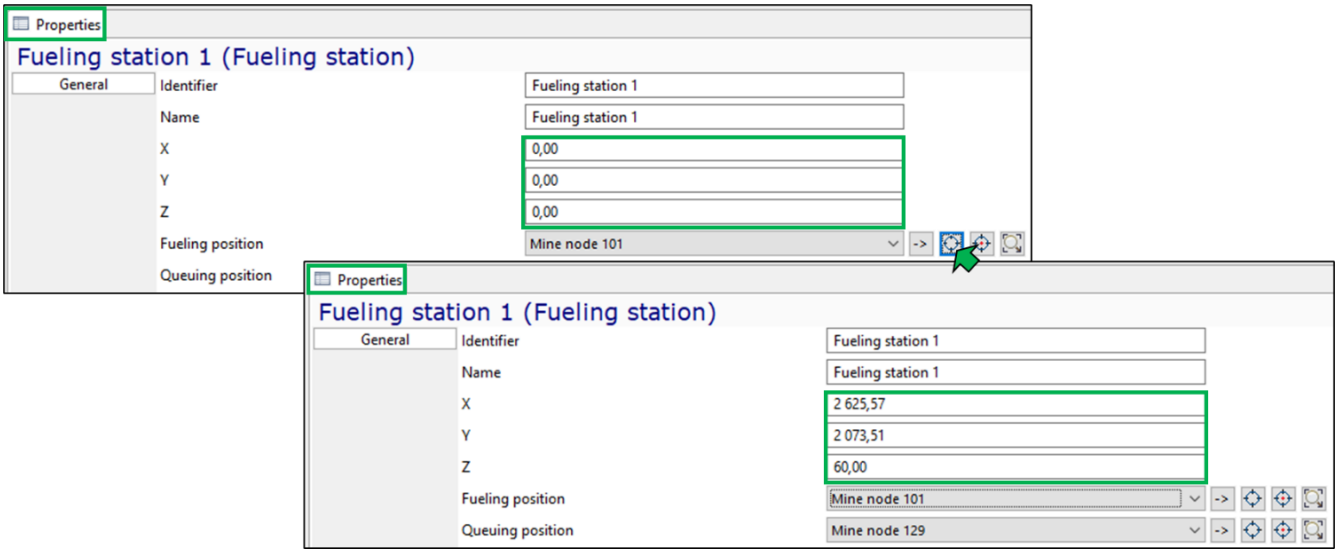
The button  allows you to define a different base node by selecting it on the map in 2D mode.



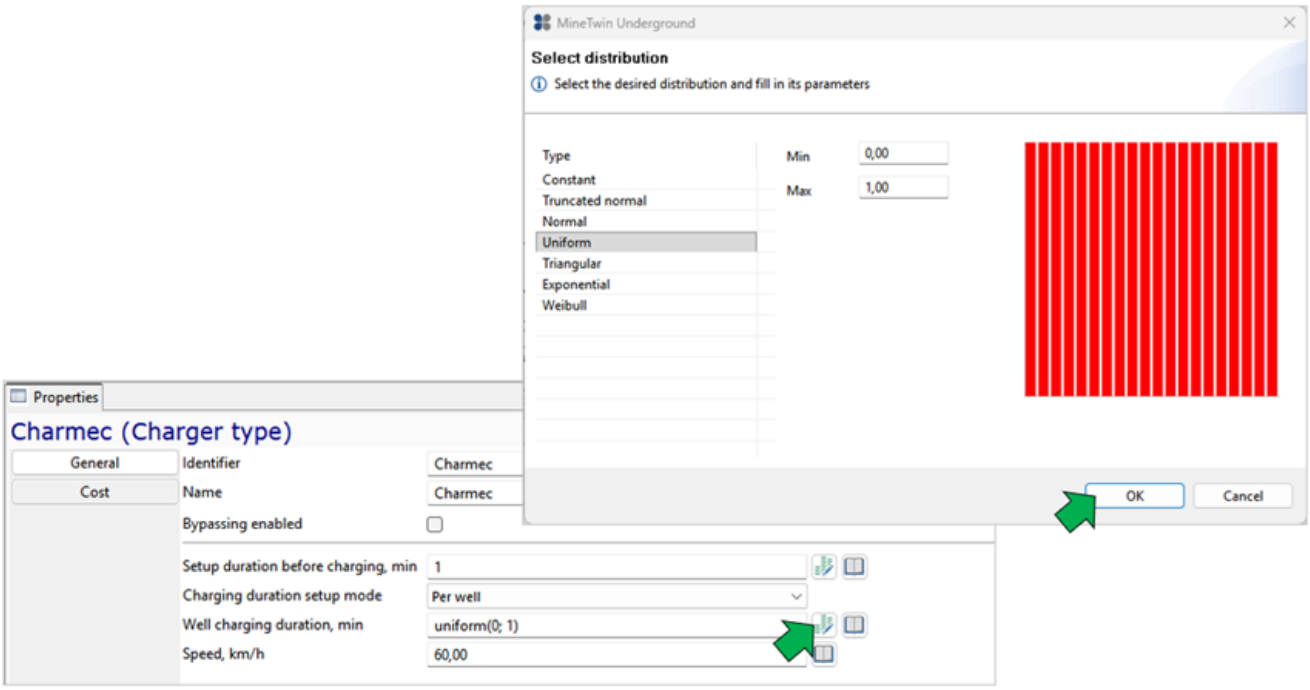
The button  highlights the selected node in the graphical editor (on a 2D map).



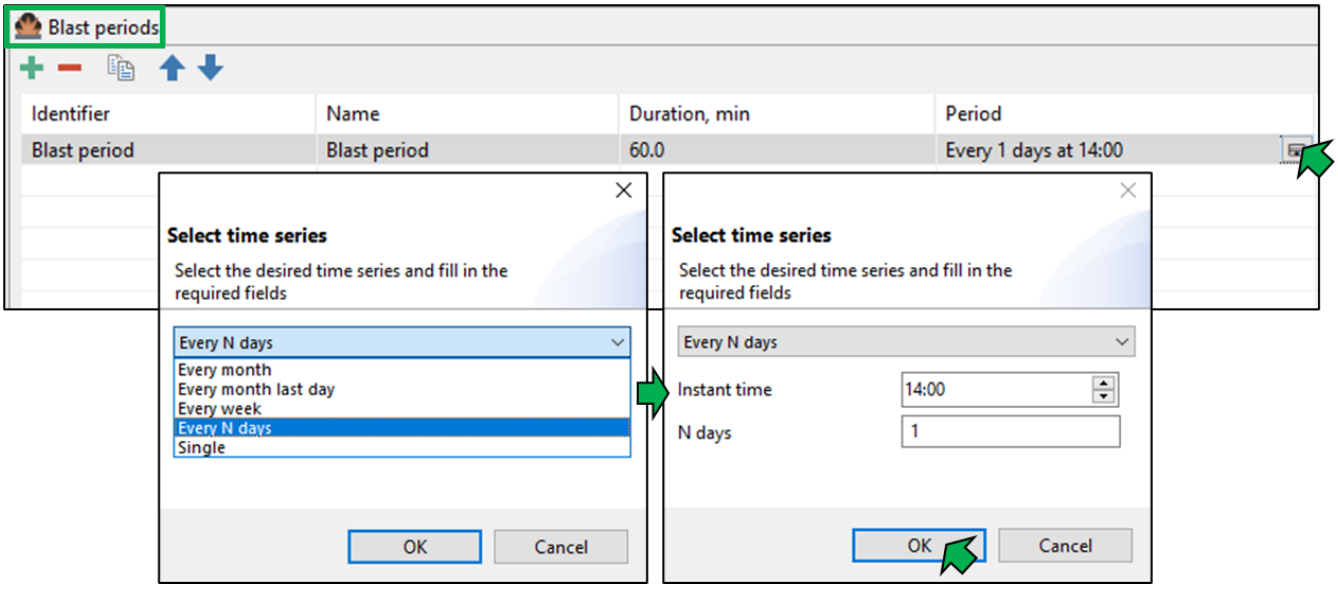
To move the object unit on the mine map to the point of its base node, use the button  .



All durations in MineTwin can be set to a constant value or one of the distributions (normal, truncated normal, uniform, triangular). To set the duration, you need to go to the pop-up window by clicking on the  button to the right of the duration value field and select the appropriate distribution in the window that appears. Alternatively, you can edit the value directly in the field.

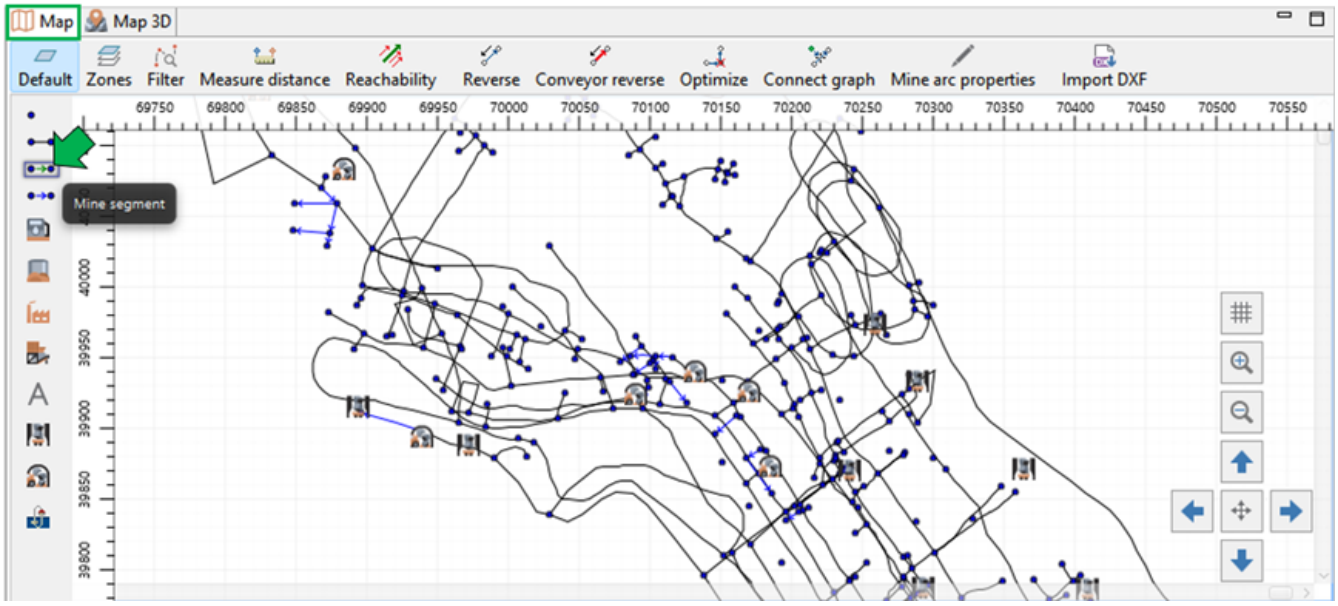


The time of occurrence of all periodic events in MineTwin can be set by the exact time or by some frequency (every n-th day of the month, every last day of the month, every week, every n days).



1.3.5. Map

The **Map** window displays a mine plan in two dimensions. The plan in this mode is editable.



Viewing control functions

Zooming in/out of the mine plan is performed by the mouse wheel while holding down the **Ctrl** key. The plan is moved with the mouse while holding down the right mouse button.

In the lower-right corner of the window, there is a map display control panel.

The button allows you to enable/disable the coordinate grid and the ruler along the window outline.

The button allows you to center the map.

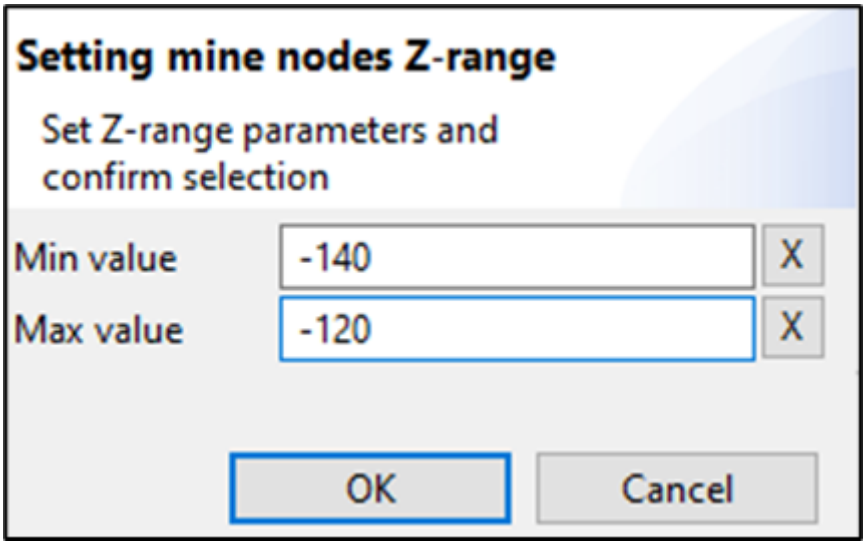
The buttons zoom in and out of the map.

The buttons allow you to move the map up, down, right, and left.

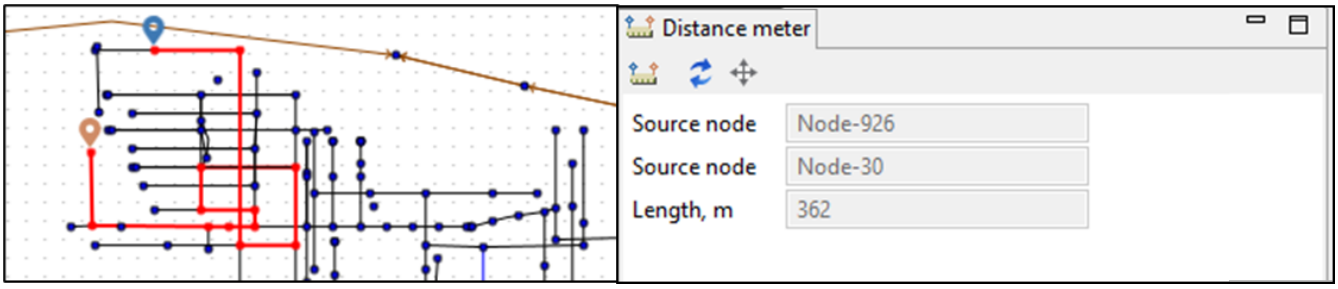
The top of the **Map** window contains a toolbar for working with transportation network graphs.

The button activates the illumination of the mine arcs by default, and the button activates the illumination of the arcs by mine zones.

In the graphic editor MineTwin Underground, the viewing of individual sections of the mine field located at a given depth is available. The button is used to set the range in the Z-coordinate of the mine nodes for viewing, for example, from -140 to -120.



The button allows us to determine the shortest distance between two nodes of the mine field. After clicking on this button, a label appears, which must be placed on the node of the beginning of the path and clicked with the mouse. Then the second label will appear, which must be set on the destination node. After that, the route between the nodes will be highlighted on the map, and information about the distance between the selected mine nodes will appear in the **Distance meter** window that opens.



To exit the distance measurement mode, use the **Esc** key.

The button highlights isolated sections of the transport network in different colors.

Map editing functions

The button allows you to quickly change the direction of the stope.

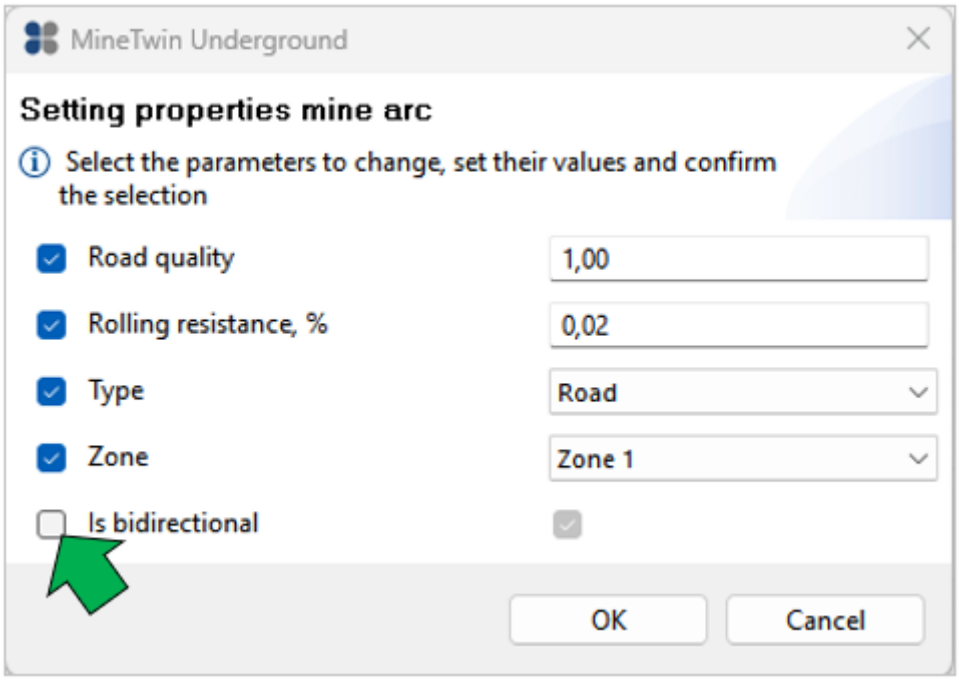
The button allows you to quickly change the direction of the conveyor.

The button optimizes arc inflection points - removes inflection points that are on the same line between two consecutive inflection points of selected mine arcs or all arcs of the scenario if no arc is selected.

The button creates a connection between a mine field arc and a node/arc, if the distance between them is less than 2.5 meters (by default). When the selected arc is merged with another arc's node, the former is split into two. If no arcs are selected, pressing this button connects all nearby arcs of the transport network according to the described rule.

The button opens a dialog box for setting the basic properties of a mine arcs group. To do this,

use the mouse to select the desired set of mine arcs on the map, click this button, activate the editable parameters, and change the values to the desired ones.



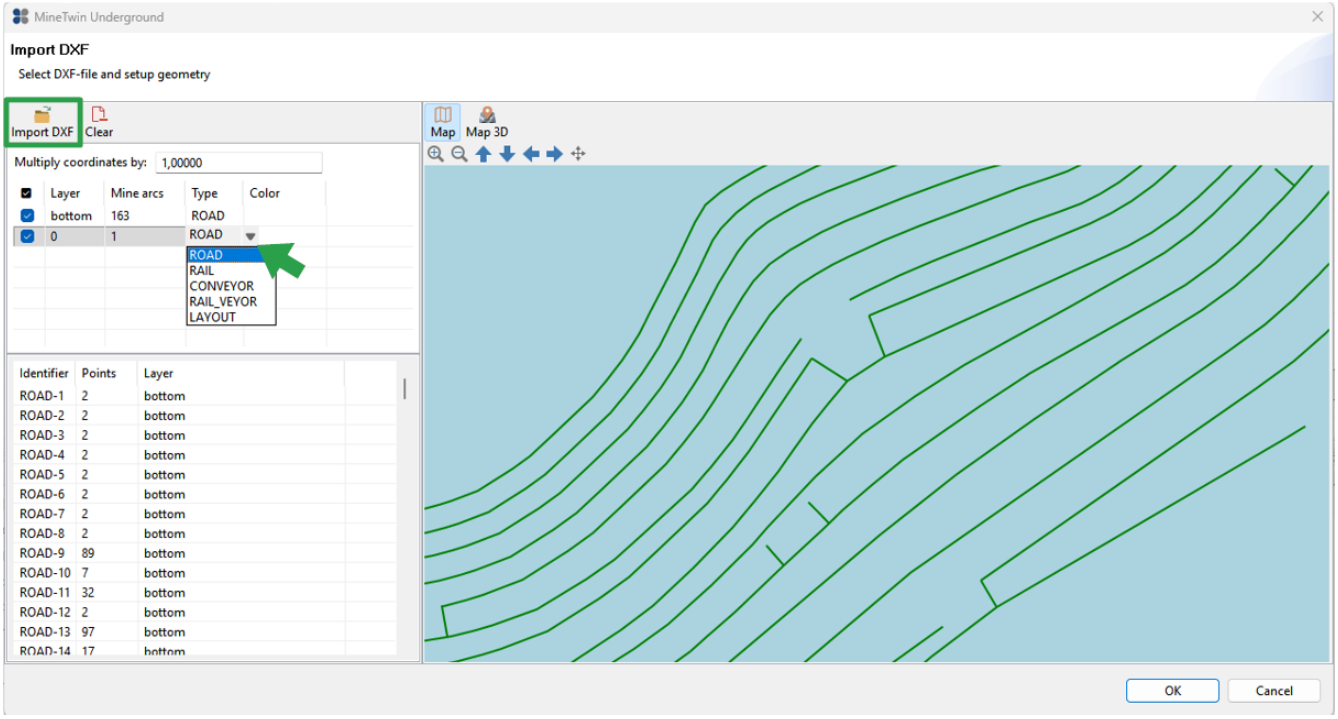
You can use the dialog box to set the following parameters in bulk:

- **Road quality**
- **Rolling resistens,%**
- **Type**: *road*, *rail*, *conveyor* or *railveyor*
- **Zone**
- **Is bidirectional** - parameter that indicates whether movement along the mine arc in both directions is possible

Importing graphical data in .dxf format

MineTwin Underground supports the import of graphic data from third-party IT systems in .dxf format. By clicking on the button , a dialog box opens where you can select the desired dxf file, select the required layers, and import them into the scenario. If the parameters of the imported topology are specified in a non-metric system (e.g., feet), you need to multiply the coordinates by the appropriate conversion factor to convert them to metric units. When importing geometry, the following line types can be assigned:

- **ROAD** — road axis for the movement of self-propelled mobile equipment
- **RAIL** — railroad track axis
- **CONVEYOR** — conveyor line axis
- **RAIL_VEYOR** — railroad track axis for rail-conveyor systems
- **LAYOUT** — polylines of the layout layer used as auxiliary elements when working with the Map; they are not involved in simulation



By default, all imported lines are assigned the ROAD type.

Left toolbar (palette)

The left panel of the editor window (Map) contains objects that can be added to the enterprise plan: mine nodes, arcs and segments, stopes, fueling and recharging stations, storages, processing plants, crushers, blenders, ore passes, cross-dock points and skip hoists.

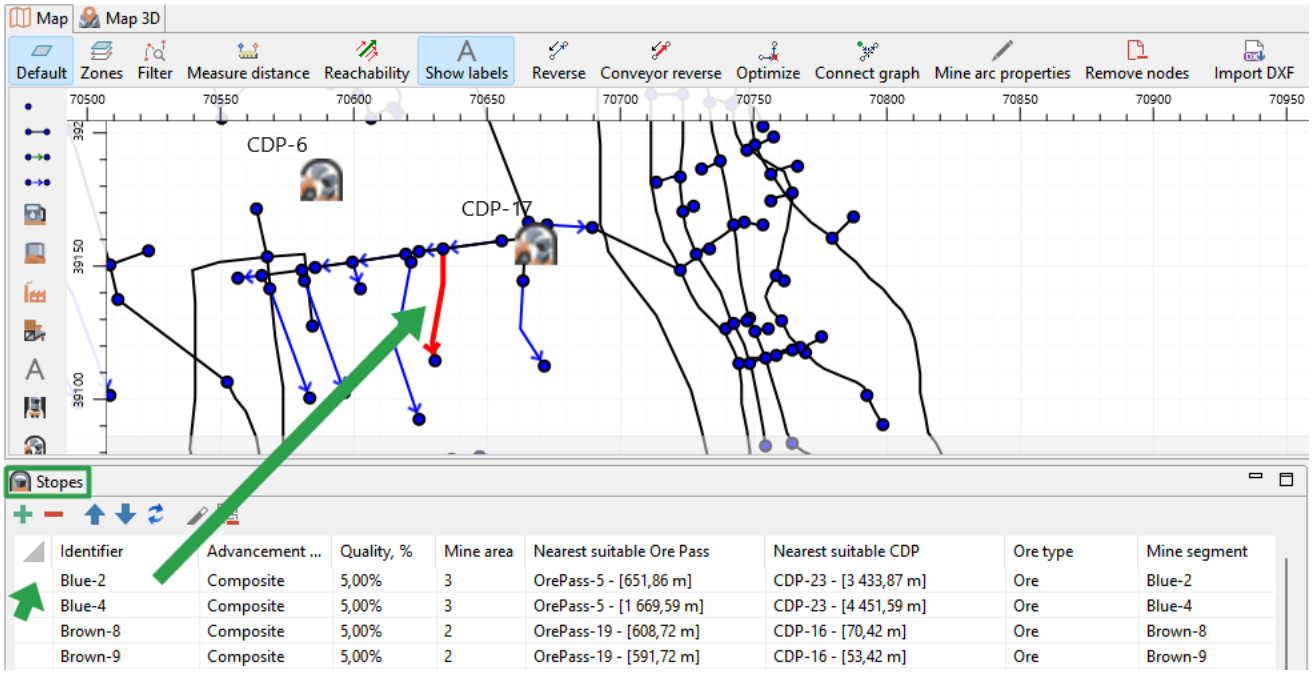
A mine polyline arc and a layout polyline are created by successively placing vertices/points of the polyline with the mouse. Drawing is completed by double-clicking the left mouse button. If you start drawing a polyline arc from a transport network node and/or finish on an existing similar node, the line connects to these nodes and arcs, forming a single network.

To add an stope or a mine segment, left-click the corresponding object on the palette, then left-click the desired arc on the map.

To add other objects from the palette, left-click the object on the palette, then click at the location on the map where you want to place the object.

In the Map window, multiple selection and moving of objects is available. To do this, select the objects with the mouse and move them using the keyboard arrow keys.

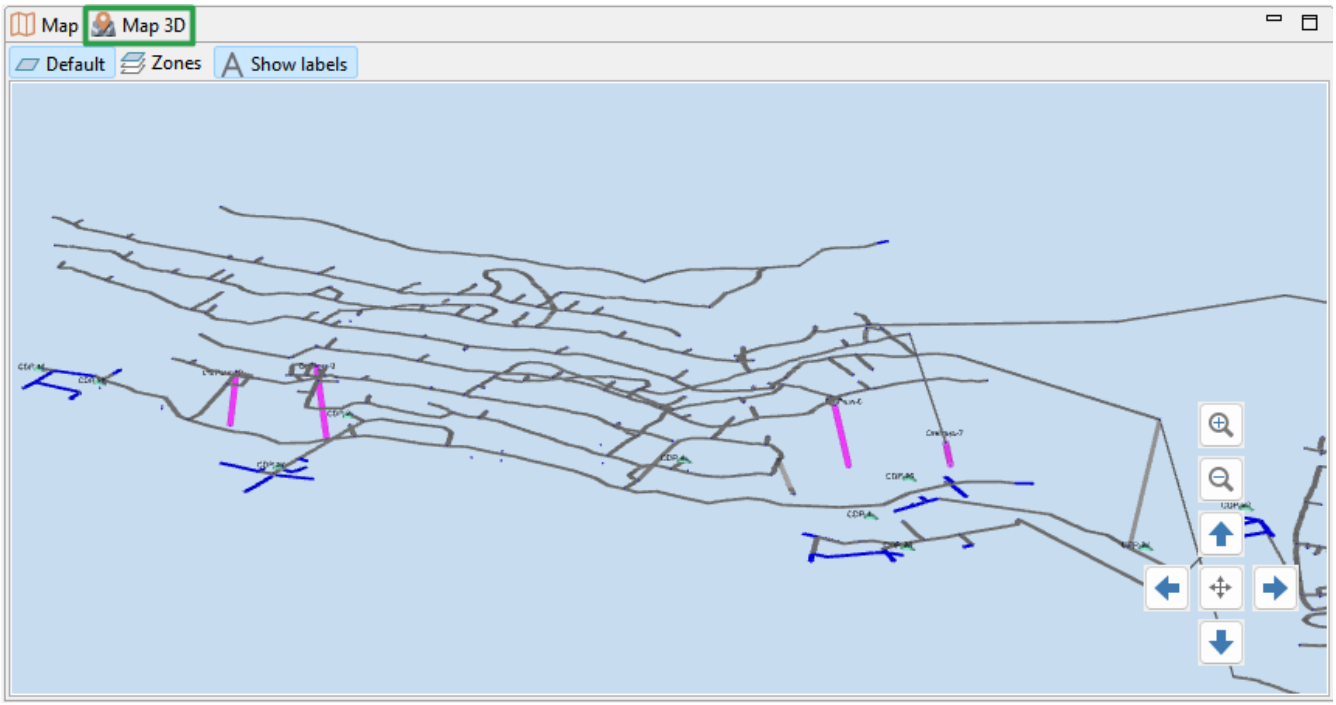
When you select the object unit in the list of objects window, the corresponding object is highlighted on the map.



Identifier	Advancement ...	Quality, %	Mine area	Nearest suitable Ore Pass	Nearest suitable CDP	Ore type	Mine segment
Blue-2	Composite	5,00%	3	OrePass-5 - [651,86 m]	CDP-23 - [3 433,87 m]	Ore	Blue-2
Blue-4	Composite	5,00%	3	OrePass-5 - [1 669,59 m]	CDP-23 - [4 451,59 m]	Ore	Blue-4
Brown-8	Composite	5,00%	2	OrePass-19 - [608,72 m]	CDP-16 - [70,42 m]	Ore	Brown-8
Brown-9	Composite	5,00%	2	OrePass-19 - [591,72 m]	CDP-16 - [53,42 m]	Ore	Brown-9

1.3.6. Map 3D

The **Map 3D** window displays a mine plan in three dimensions. The plan in this mode is available only for viewing.



The plan is moved with the mouse while holding down the left mouse button, rotation is done while holding down the right mouse button.

The model display control panel is located in the lower-right corner of the window.

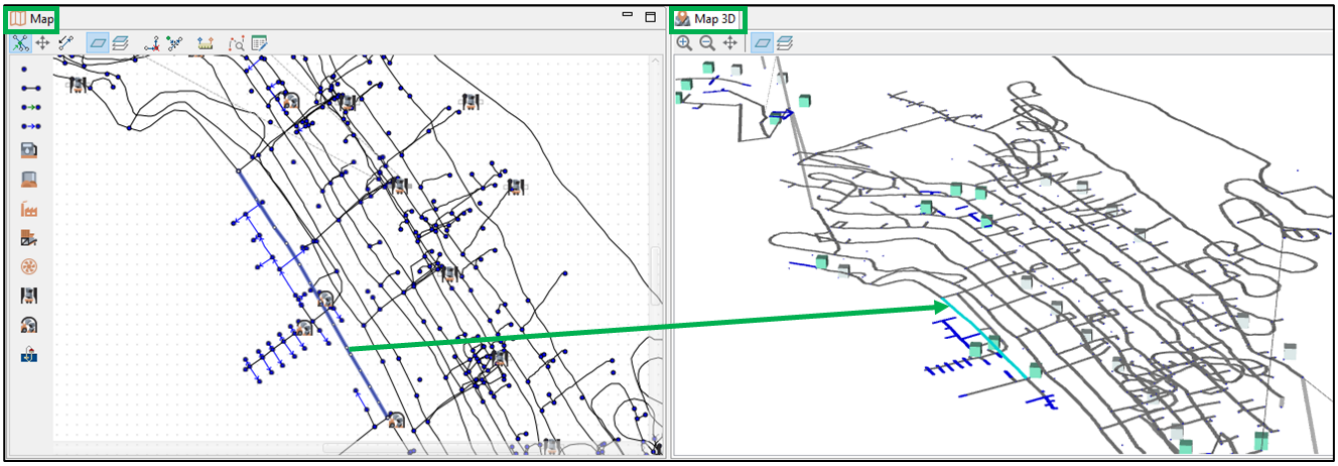
The button allows you to center the 3D map.

The buttons allows you to zoom in and out on the 3D map of the mine.

The button activates the illumination of the mine arcs by default, and the button activates

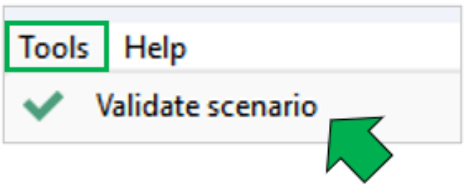
the illumination of the arcs by mine zones, Show labels hides/shows text labels.

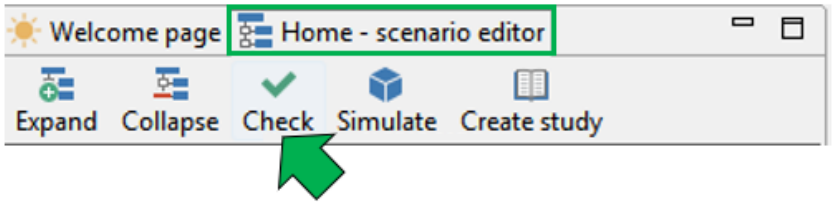
Maps in 2D and 3D are synchronized: when you select an object on one map, it is highlighted on the other.



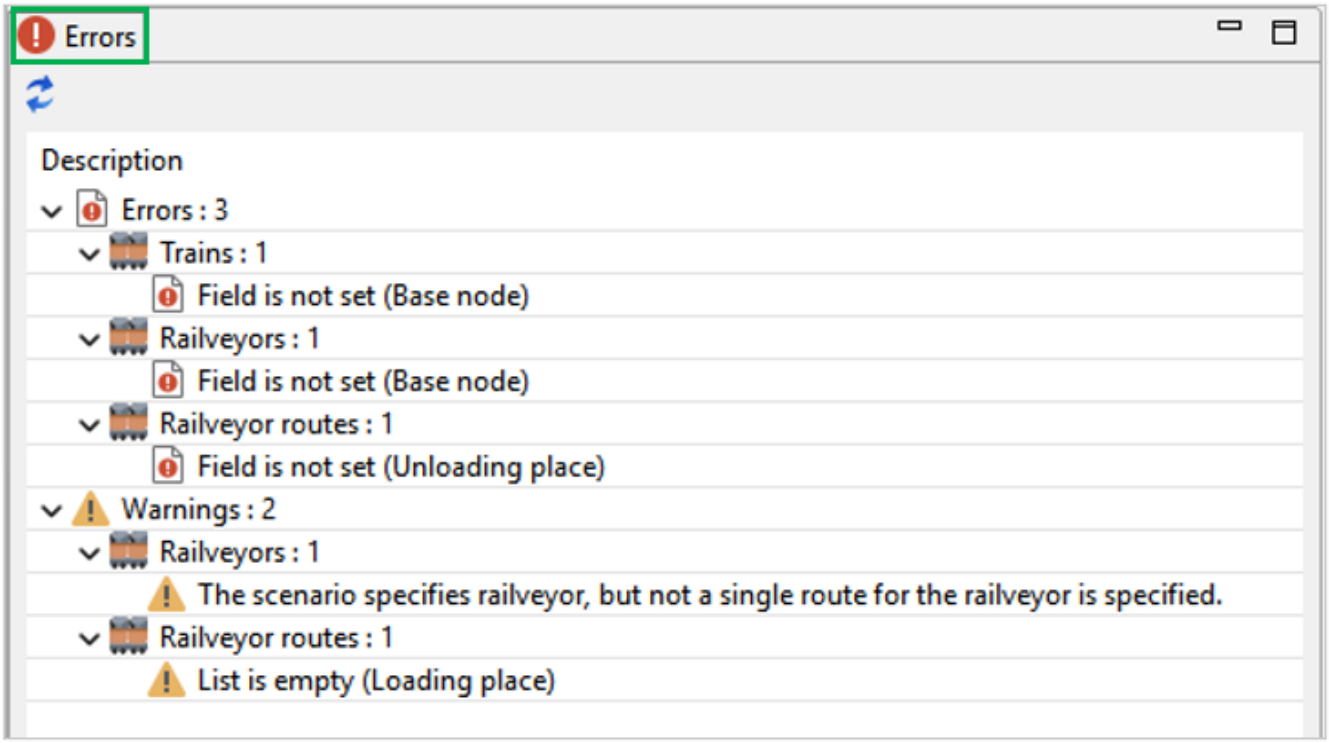
1.3.7. Errors

After creating/editing a scenario, you need to check its correctness using the *Validate scenario* button in the **Tools** button menu on the toolbar or by using the **Check** button in the editor toolbar.





If the data is set incorrectly or there is not enough data, an error message will appear, a list of which will be shown in the **Errors** window.



Error messages can be of two types:

- errors that make scheduling impossible;
- warnings about the lack of some data that do not interfere with scheduling.

Clicking on each line of the error list in the **Properties** window opens the properties of the object in which the error occurred, and the user can quickly fix it.

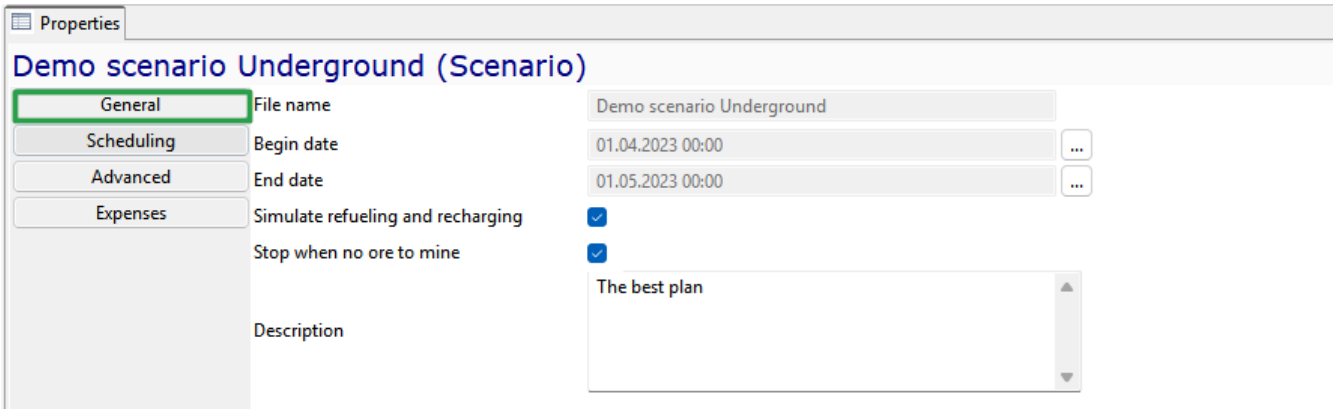
The button in the upper right corner of the **Errors** window serves to update the error list after they have been fixed.

1.4. Scenario

The **Scenario** object tree element contains global parameters related to the scheduling and simulation of an underground mine.

On the **General** tab, you will find:

- **File name**
- **Begin and end date** - date and time for planning and simulation
- **Simulate refueling and recharging** - when checked, refueling and recharging are simulated; when unchecked, fuel and energy demand is calculated but the movement to the station and the refueling/recharging process are not simulated
- **Stop when no ore mine** - stop the simulation if there is no ore remaining in the mining fronts, even if specified end date has not yet been reached
- **Description** — comments on the scenario (optional)

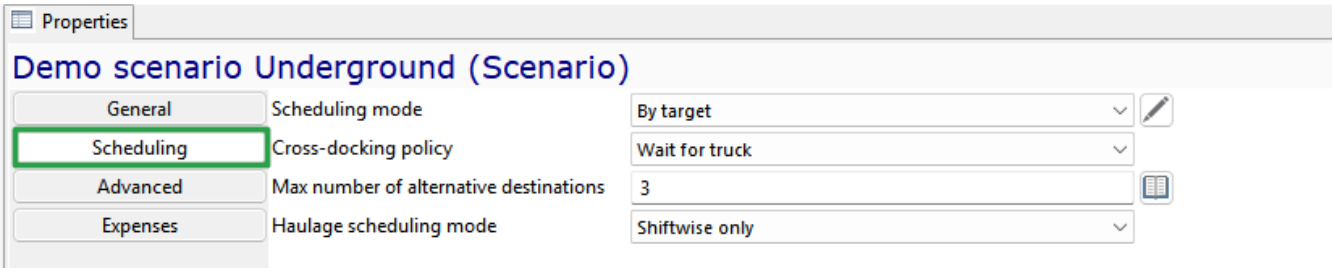


The **Scheduling** tab contains parameters that define the planning rules:

- **Scheduling mode** — one of the possible scheduling modes:
  - *by stopes* - scheduling is carried out according to the plan the by stopes
  - *by target* - scheduling is carried out in accordance with the plan the by target, which defines how much ore mass and of what quality must be extracted in each planning period for the entire mine
- **Target adherence type** — one of two options for target adherence policy:

- *Maximize mass with exact match to grade* — the scheduler tries to meet the planned ore quality and volumes. It does not exceed planned production volumes even if there are free work faces and equipment. If work faces, equipment, or ore of the required quality are insufficient, the scheduler prioritizes achieving the target ore quality, even at the cost of reducing tonnage
- *Maximize mass regardless of grade* — the scheduler maximizes production regardless of quality. It seeks to reach target volumes for both ore and waste and to avoid situations where one target is missed while the other is greatly exceeded. After hitting both targets, equipment is distributed approximately evenly between ore and waste to maximize both

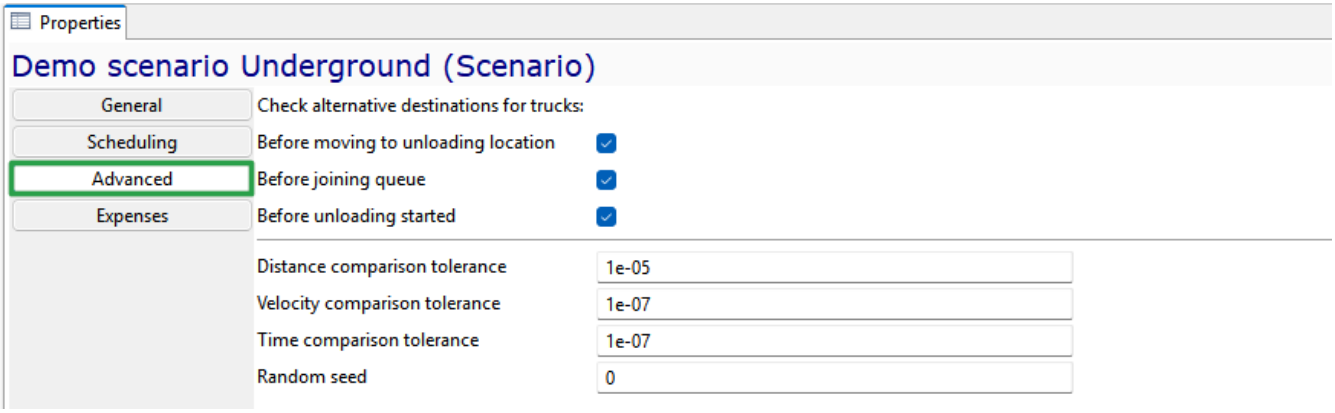
- **Excavator relocation distance quantum, m** — this parameter defines the search radius for an excavator's next work location. After an excavator completes work in a block, its next work location is searched for within the specified radius. When all blocks within this radius have been processed, the radius is doubled, and the search for a work location is conducted within the new, doubled radius. If no work is found there either, the search is performed across any range
- **Percentile for RV estimation, %** – a technical parameter that defines the fluctuation range of random variables. The result of the calculation is a number that does not vary during the planning process. For example, with a uniform distribution of operation duration from 5 to 10:
  - If the percentile is set to 0% – the minimum possible value of 5 will be used in planning
  - If the percentile is set to 100% – the maximum possible value of 10 will be used in planning
  - If the percentile is set to 20% – the value 6 will be used in planning, because with 20% probability in a uniform distribution from 5 to 10, the value will be between 5 and 6
  - If the percentile is set to 40% – the value 7 will be used
- **Haulage scheduling mode**:
  - *Shiftwise only* – tasks are generated only at the start of each shift and are not updated during the shift
  - *Dynamic only* – a new task is assigned to each haul truck immediately upon completion of its previous trip
  - *Shiftwise and dynamic* – tasks are generated on a shift basis but are supplemented dynamically if a truck becomes idle (e.g., due to excavator breakdown or early completion of work).



The **Advanced** tab contains additional technical settings

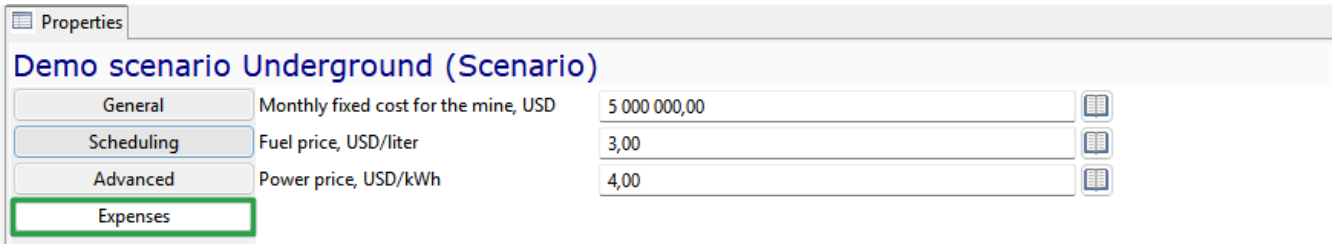
When to check the fill level of the planned dump location and choose alternative dump locations for trucks:

- **Before moving to unloading location** - when this parameter is enabled, trucks will check the fill level of the scheduled dump area/ ore pass before beginning to unloadw
- **Before joining queue** - when this parameter is enabled, trucks will check the fill level of the scheduled dump area/ ore pass before joining the queue for unloading
- **Before unloading started** - when this parameter is enabled, trucks will check the fill level of the scheduled dump area/ ore pass before starting to travel to the dump area/ ore pass.
- Precision settings for comparing **Distance**, **Velocity**, and **Time** during simulation
- **Random seed** — an initial value used in random number generators to create a sequence of random numbers. It serves as a "starting point" that determines which numbers will be generated. Using the same random seed ensures that the simulation results for a scenario are identical on every simulation run. Running the same scenario with a different random seed may produce different simulation results.



On the **Expenses** tab, you specify:

- **Monthly fixed costs of the pit/mine, USD**
- **Fuel price, USD/liter** to be used when calculating fuel costs
- **Power price, USD/kWh** - for charging self-propelled equipment with electric motors (rechargeable batteries).



1.5. Map

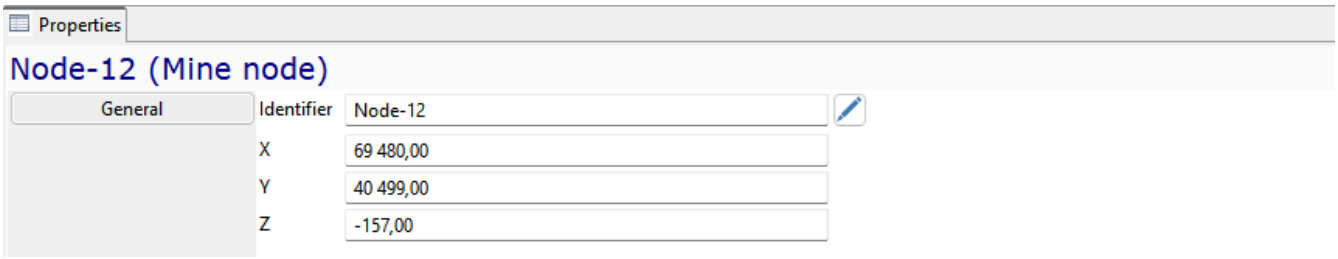
The **Map** model tree element contains the following elements of an underground mine:

- Mine nodes
- Mine arcs
- Zones
- Mine areas

- Mine segments
- Layout layers

1.5.1. Mine nodes

Mine node - an element of the mine transport network graph which corresponds to one point in two-dimensional space.

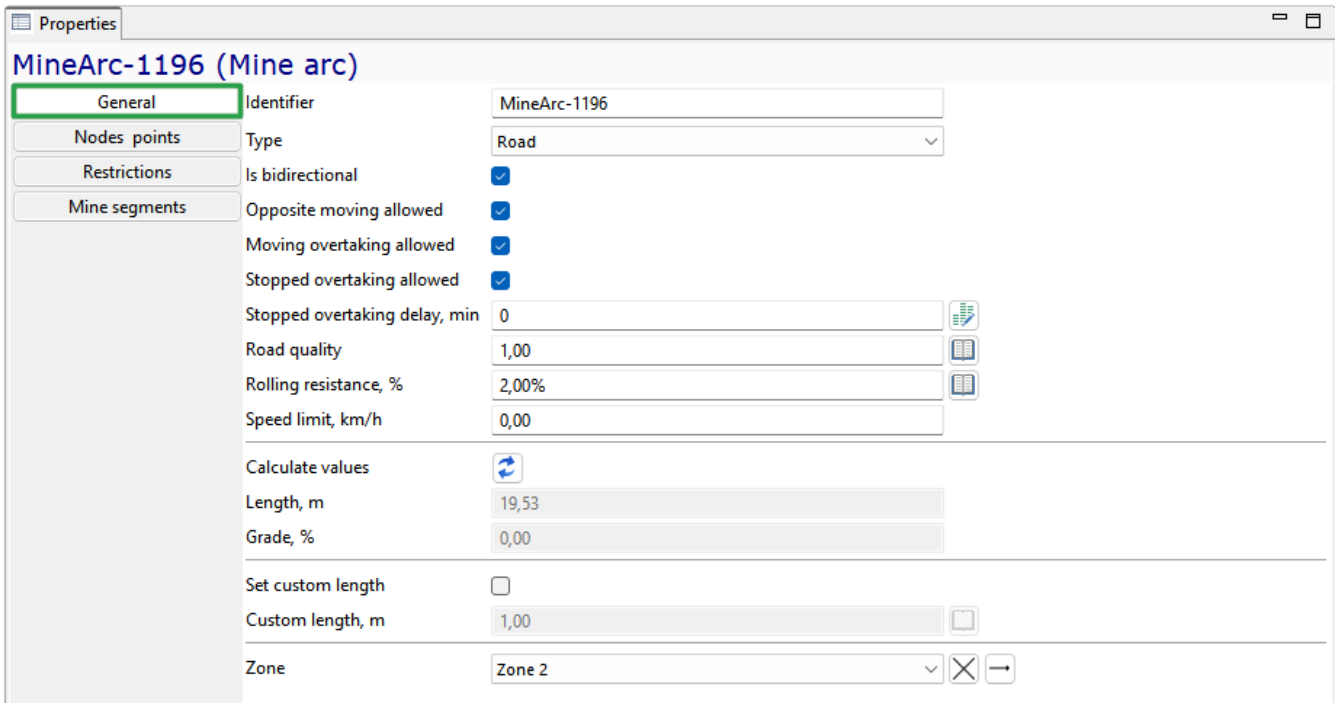


The mine node is characterized by the following parameters:

- Unique **identifier**
- **X**-, **Y**- and **Z**-coordinates

1.5.2. Mine arc

Mine arc - an element of the transport network graph that connects two mine nodes.

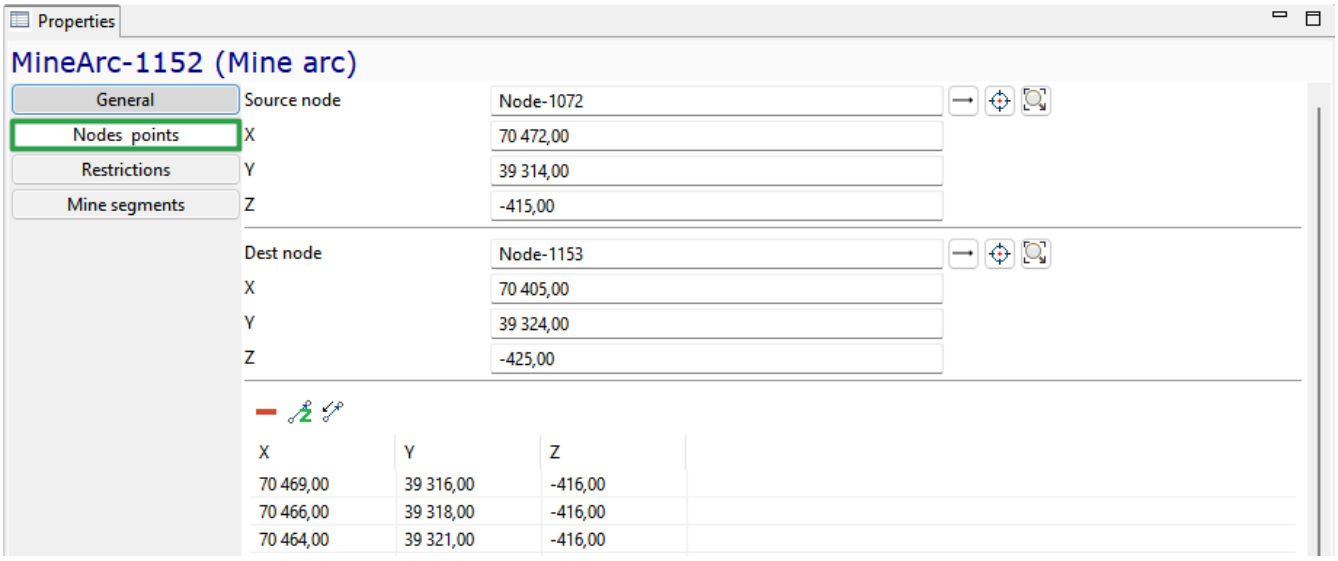


The mine arc is characterized by the following parameters:

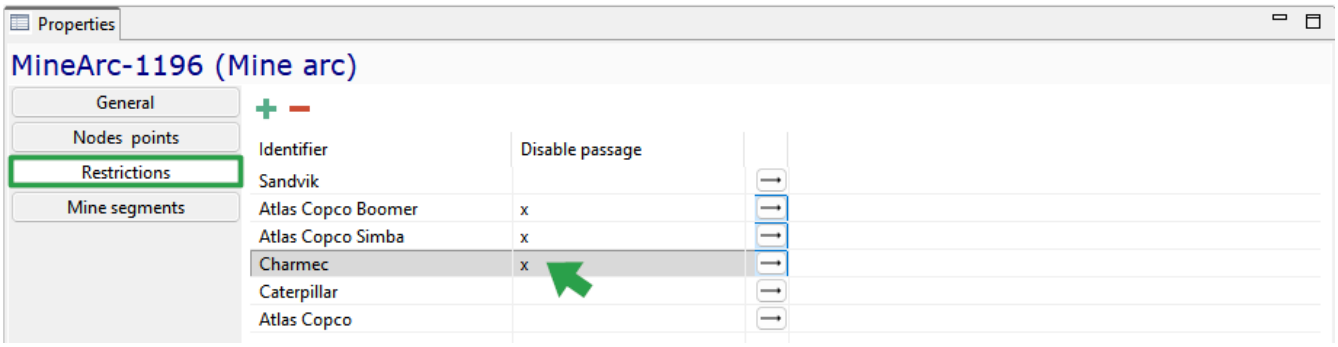
- Unique **identifier**
- **Type** — one of the following types: Road (non-rail), Rail, Conveyor or Railveyor
- **Is bidirectional** — parameter indicating whether travel along this mine arc is possible in both directions (two-way road)

- **Opposite moving allowed** — a parameter specifies whether simultaneous movement in the opposite direction is allowed. If not, the equipment will stop in front of the arc to allow those traveling in the opposite direction to pass
- **Moving overtaking allowed** — a parameter specifies whether passing of slower vehicles traveling in the same direction is permitted on this arc
- **Stopped overtaking allowed** — a parameter specifies whether a moving vehicle may overtake or bypass a stopped vehicle on this arc
- **Stopped overtaking delay, min** — a parameter defines the additional delay required for a vehicle to overtake or bypass a stopped vehicle on this arc
- **Road quality** — a factor that adjusts the base speed of equipment when traveling along this mine arc
- **Rolling resistance, %** — the resistance that occurs when tires of self-propelled wheeled equipment roll on the road surface. This parameter affects the equipment's travel speed when the speed calculation rule "Rimpull curve based" is applied
- **Speed limit, km/h** — maximum speed of movement for all moveable equipment on this arc. The actual speed can be lower due to individual equipment settings
- **Length** — system-calculated length of the segment, taking into account the mine arcs it comprises
- **Grade, %** — arc gradient (slope) is automatically calculated by the system as the ratio of the vertical rise (difference in z-coordinates) to the arc length, expressed as a percentage
- **Set custom length** — parameter allowing to set an arbitrary length for the mine arc, disregarding actual coordinates and scaling
- **Custom length,m** — conditional/override length of the mine arc
- **Zone** — zones serve for color-coding mine arcs. For example, a user can create a transport network zone indicating roads requiring clearing and then apply this zone (color) to all arcs that need clearing

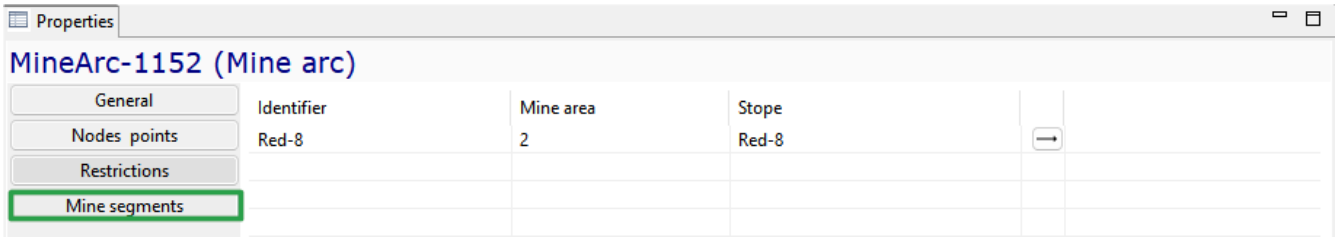
A separate tab of the properties of the mine arc displays the **Nodes points** of the arc - references to the start and end node of the mine arc and the list of broken line points (arc inflection points).



In the **Restrictions** group, you can prohibit the movement of certain types of equipment along the arc of the transport network by checking the box next to them.

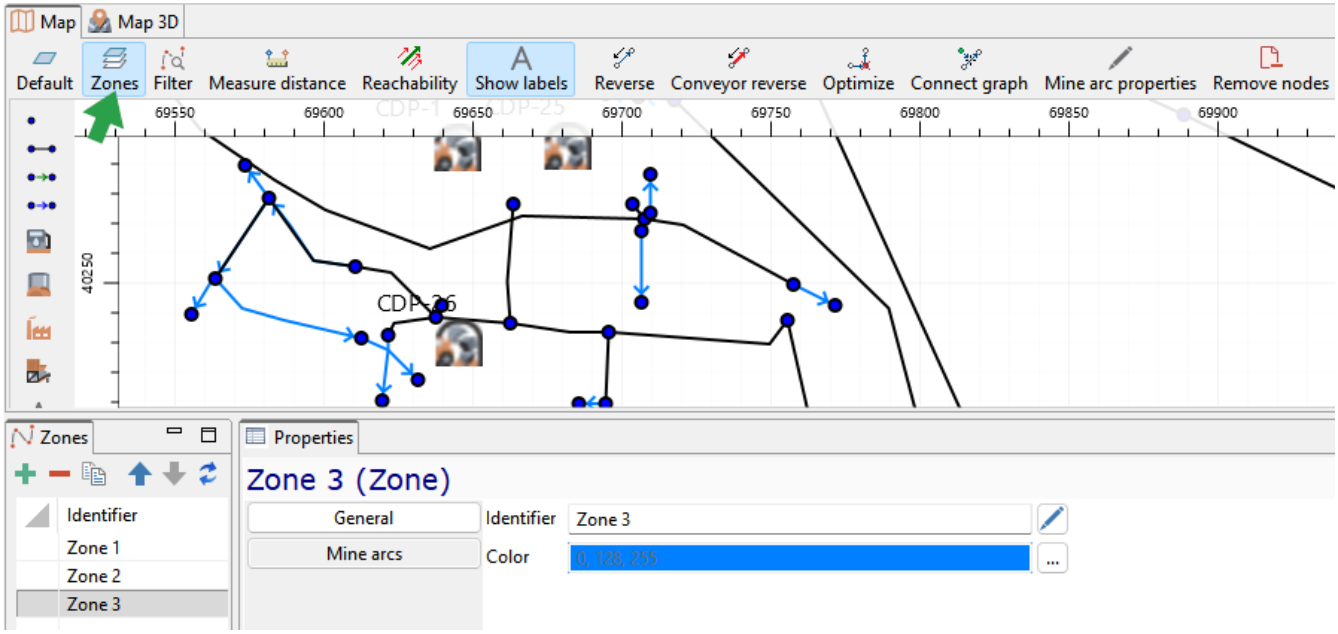


Reference to the mine segment of which this arc is a part is displayed in the **Mine segments** tab of the arc properties.



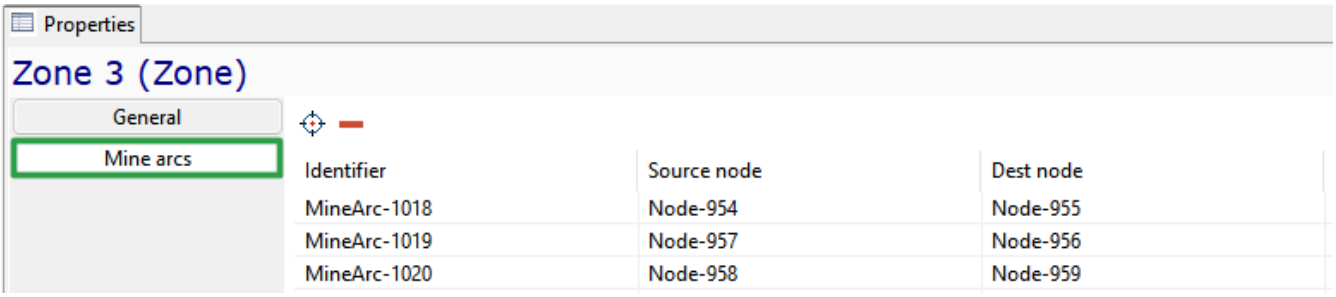
1.5.3. Zone

The **Zone** object defines a list of color options for arcs on the mine field map. For example, a user can create a mine field zone that represents roads that need to be cleared, and then apply this zone (color) to all arcs that require clearing.



The zone is characterized by a unique **identifier** and **color**.

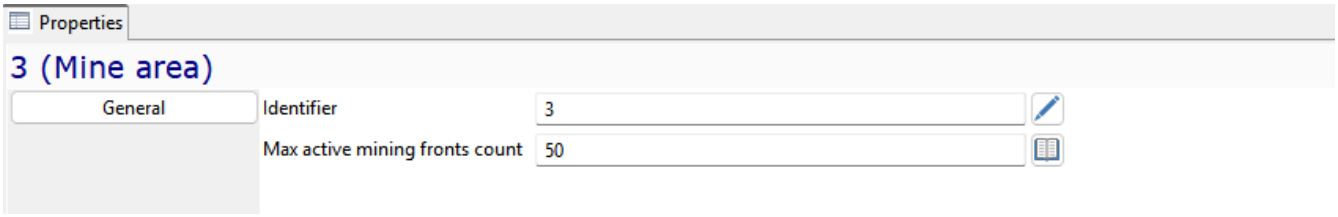
The **Mine arcs** tab of the zone properties contains a list of the mine arcs included in this zone.



Here, you can add arcs by selecting them on a mine field using the button  or remove an arc from the list ().

1.5.4. Mine area

A mine area is used to logically combine several adjacent stopes. Specific equipment/ transport unit may be assigned to areas.

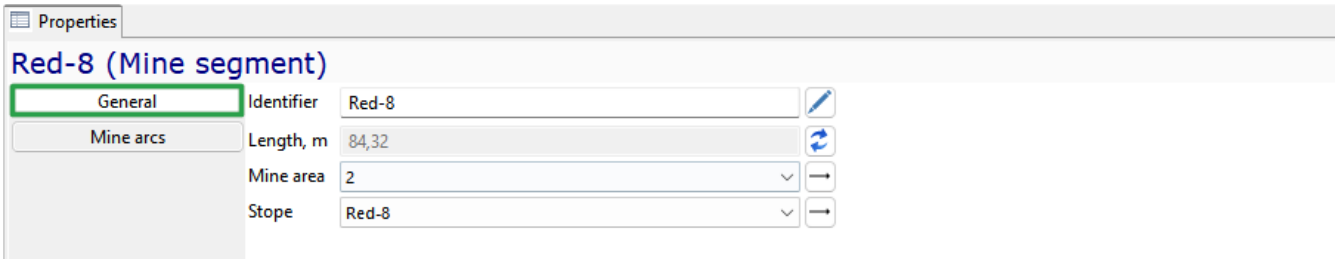


A site in MineTwin Underground is characterized by the following main parameters:

- Unique **identifier**
- **Maximum active mining fronts count** in simultaneous operation is a parameter that limits the work on the site, even if there is enough equipment. For example, there are 10 workings available for mining, but the user has set a limit of 5. In this case, only 5 workings will be mined. Work on the sixth working will begin only after one of the first 5 workings has been completed, and so on.

1.5.5. Mine segment

Mine segment - an ordered set of mine arcs used to define the location of a stope. A mine segment corresponds to a directed broken line in three-dimensional space.

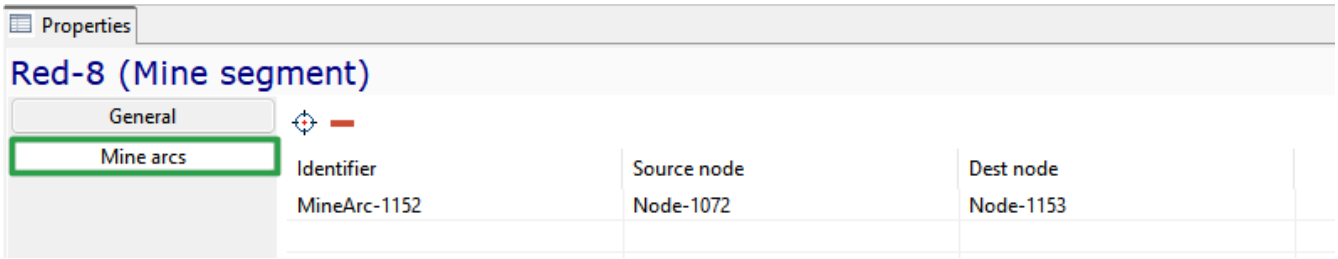


The mine segment is characterized by the following main parameters:

- Unique **identifier**
- **Length, m** - automatically calculated as the sum of the lengths of the mine arcs of which this segment consists
- **Mine area** - a mine area to which this mine segment belongs

- **Stope** - a reference to a stope to which this segment corresponds.

The **Mine arcs** tab of the mine segment properties contains a list of the mine arcs that this segment consists of.



Here, you can add arcs by selecting them on a mine field using the button  or remove an arc from the mine segment ().

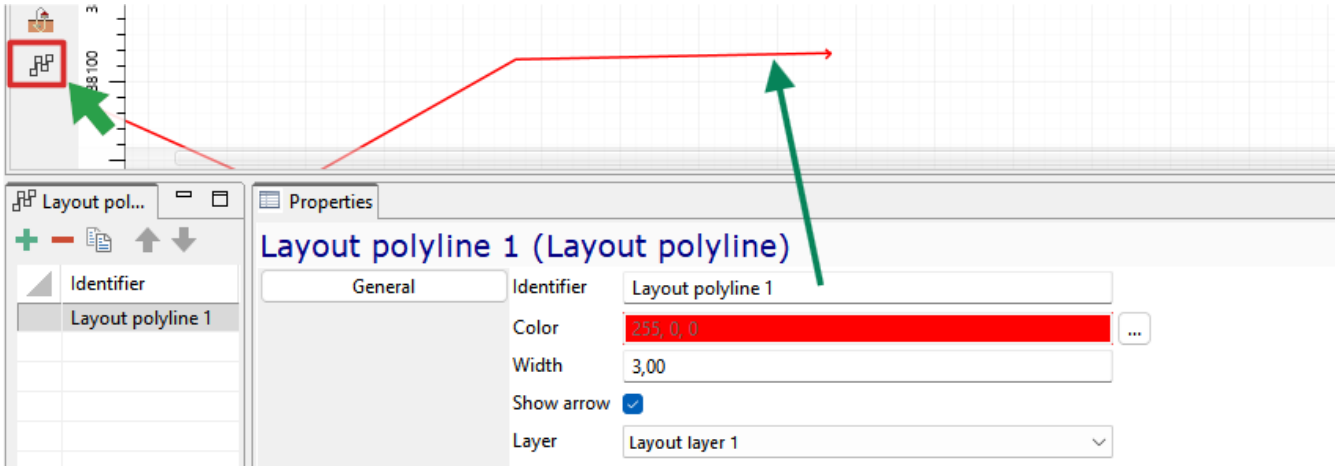
1.5.6. Layout layers

The **Layout layers** element of the object tree contains a list of layers, each of which includes two groups of objects: **Layout polylines** and **Text labels**. Layout layer objects serve as supplementary information when working with the map and are not involved in modeling. Layer properties allow enabling/disabling its visibility and editability.

Layout polylines

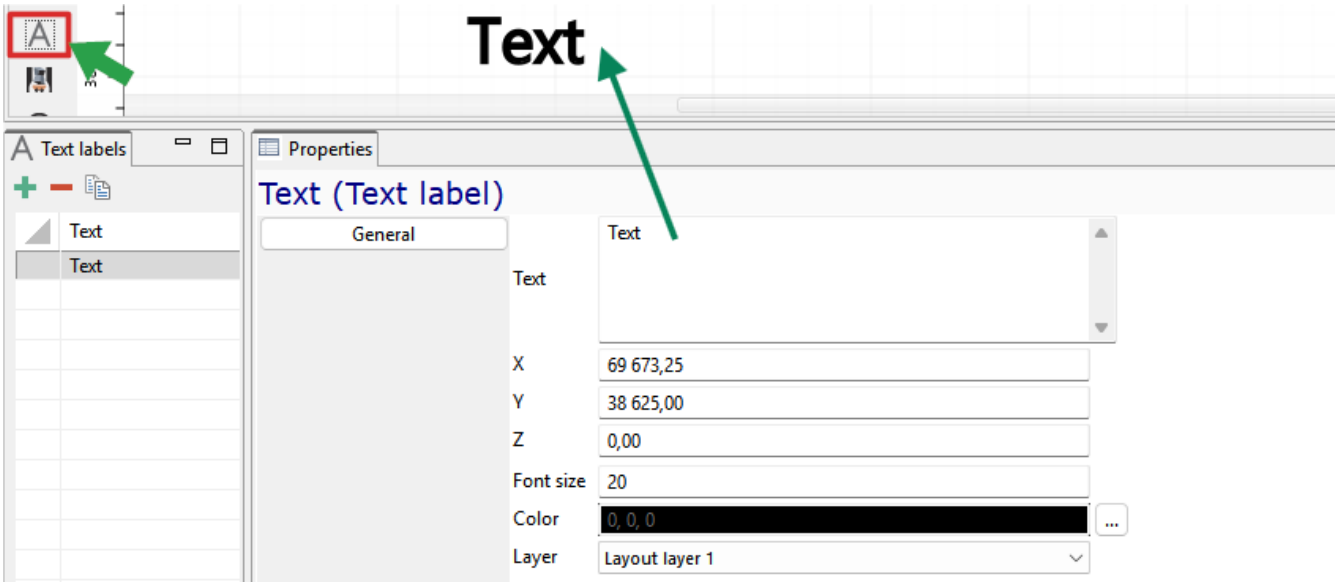
The **Layout polylines** group of the selected **Layout layer** contains a set of polylines created in the application or imported from a .dxf file. Adding a new element to the map is possible using the  button from the palette located on the left side of the 2D map window. Polyline properties include:

- Unique **Identifier**
- **Color** — ability to set the color by selecting from a palette
- **Width** — line thickness in pixels
- **Show arrow** — function to enable/disable the display of an arrow at the last point of the polyline
- **Layer** — move the layout polyline to the desired layer by selecting from the list of available layout layers



1.5.7. Text labels

The **Text Labels** element lists the text labels added to the map. You can add a new item to the map using the A button from the toolbar on the left side of the 2D map window. In the properties window you can enter the label text and set the font size and color, assignment to a layout layer from the list of those available in the scenario.



1.6. Energy

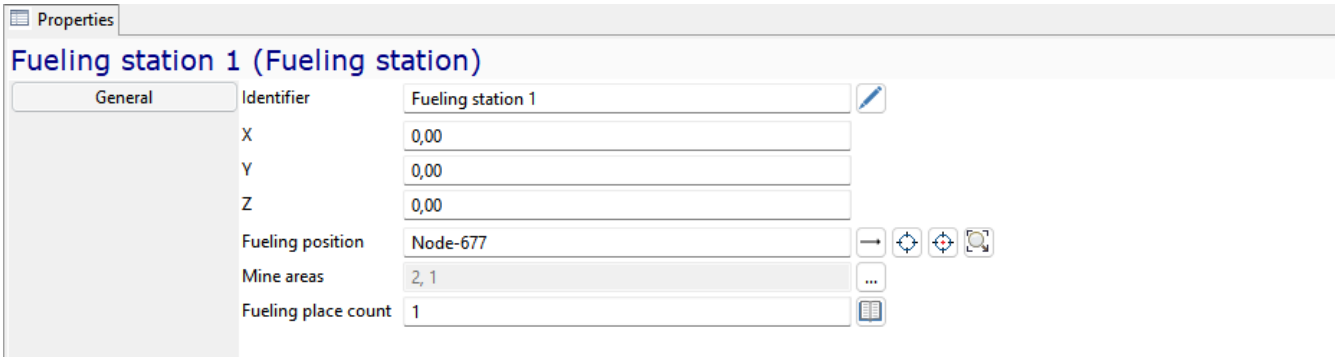
Energy object tree group contains the following mine/pit elements:

- Fueling stations
- Recharging stations
- Recharging bays
- Fixed battery types
- Swappable battery types

1.6.1. Fueling station

Fueling station - a piece of stationary equipment designed for refueling transport and equipment

units.

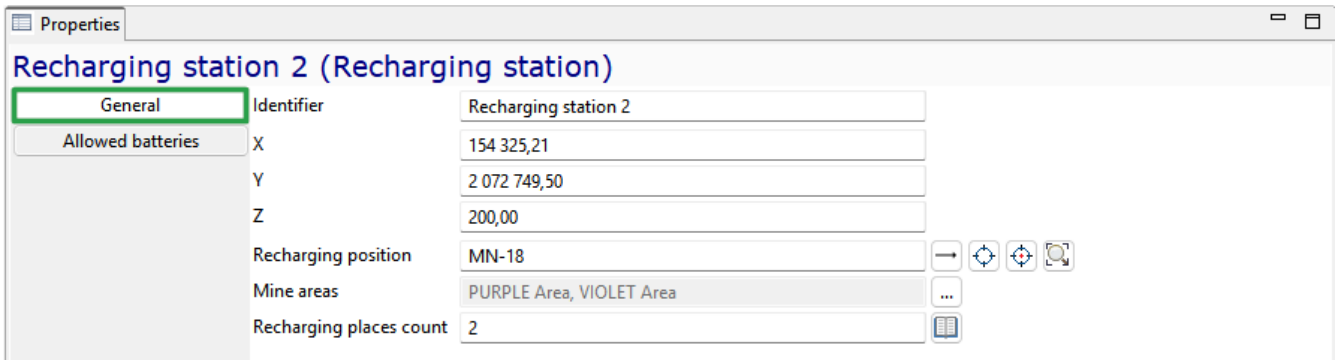


The fueling station has the following parameters:

- Unique **Identifier**
- **X-**, **Y-** and **Z**— coordinates
- **Fueling position** — link to the mine node where the equipment unit is located while refueling at the fueling station
- **Mine areas** - when specifying areas, this fueling station will only serve self-propelled equipment that belong to those areas
- **Fueling place count** - number of simultaneous refueling positions

1.6.2. Recharging stations

Recharging stations — a transport infrastructure element designed for recharging batteries that are structurally integrated into the equipment and cannot be removed from it.

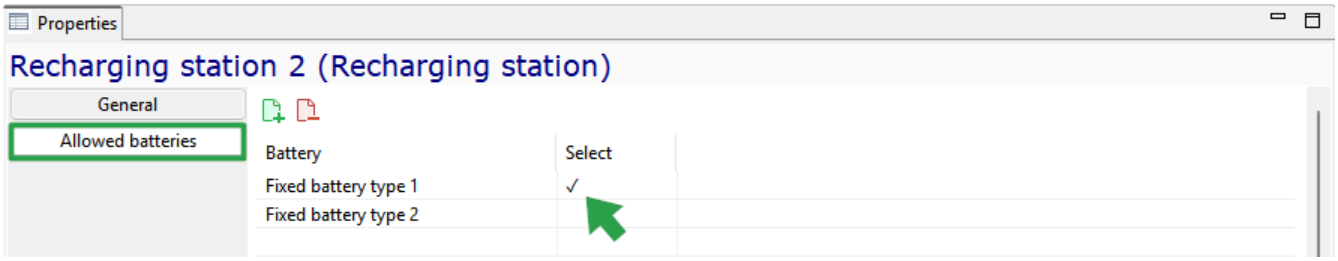


The **General** properties of a recharging stations include:

- Unique **Identifier**
- **X**, **Y**, and **Z**— coordinates of the transport network node at which the station is located
- **Recharging position** — identifier of the transport network node at which the equipment unit is positioned during battery recharging
- **Mine areas** — mine areas whose equipment may be recharged at this station
- **Recharging places count** — number of equipment units that can be recharged simultaneously at this station.

On the **Allowed batteries** tab, you may select from the list the types of fixed batteries that can be

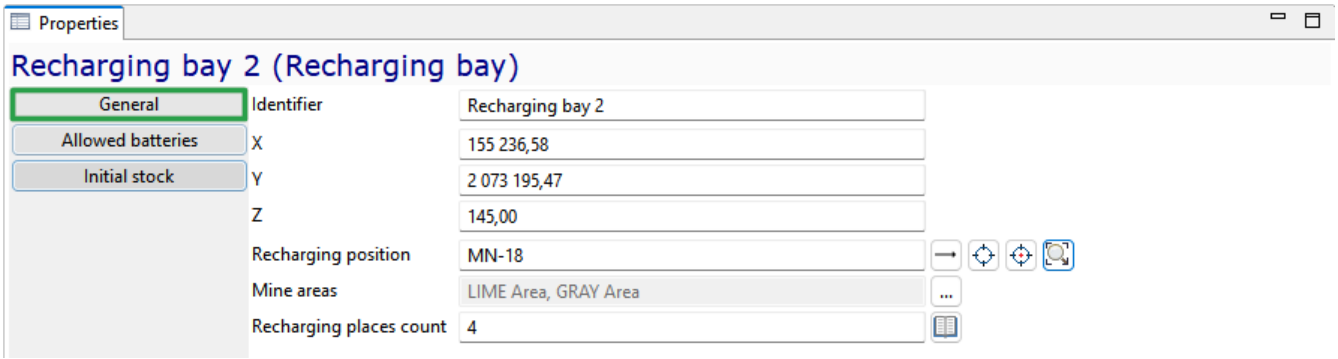
recharged at this station. The types and specifications of fixed batteries are populated in the **Fixed battery types** object group.



To select the permitted types, tick the **Select** field. The button allows you to select the entire list of fixed battery types, while the button clears all selections.

1.6.3. Recharging bays

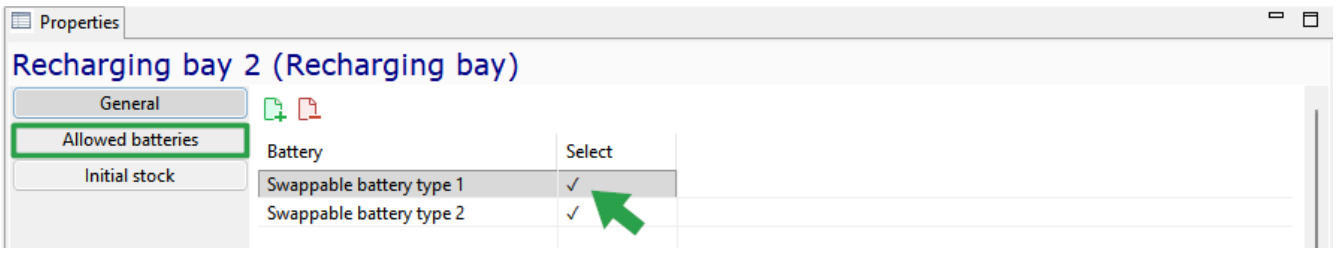
Recharging bays — a transport infrastructure element designed for exchanging depleted batteries with fully charged ones and for recharging discharged batteries.



The **General** properties of a recharging bays include:

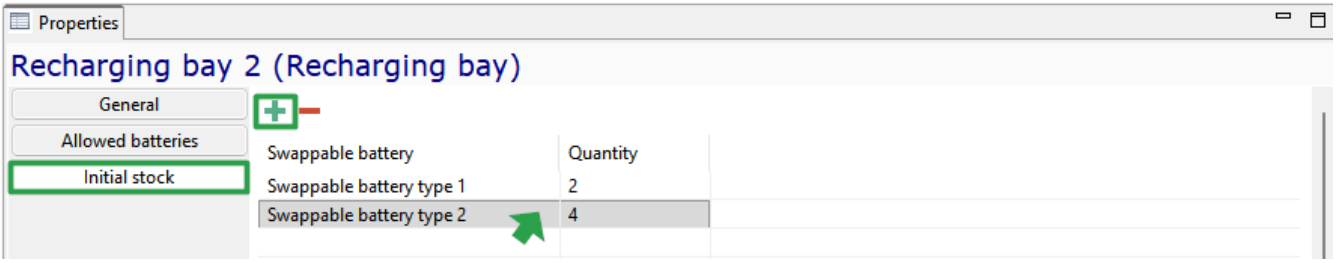
- Unique **Identifier**
- **X**, **Y**, and **Z**— coordinates of the transport network node at which the station is located
- **Recharging position** — identifier of the transport network node at which the equipment unit is positioned during battery recharging
- **Mine areas** — mine areas whose equipment may be recharged at this station
- **Recharging places count** — number of equipment units that can be recharged simultaneously at this station.

On the **Allowed batteries** tab, you may select from the list the types of swappable batteries that can be recharged at this station. The types and specifications of swappable batteries are populated in the **Swappable battery types** object group. To select the permitted types, tick the **Select** field.

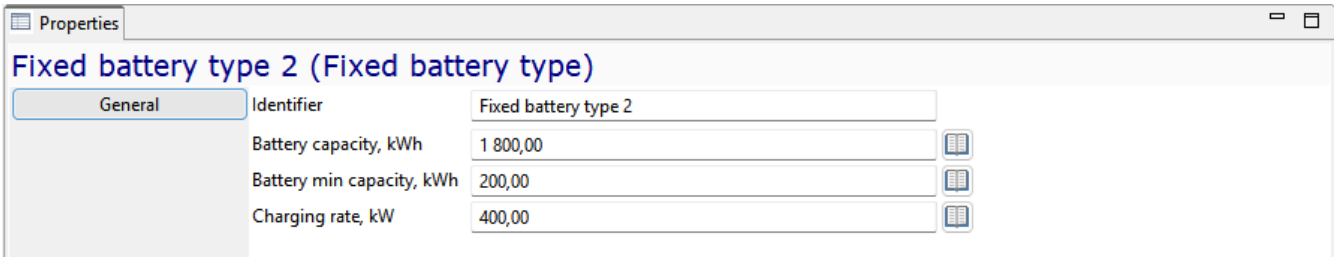


The button allows you to select the entire list of swappable battery types, while the button clears all selections.

On the **Initial stock** tab, specify the quantity of fully charged batteries of each type (if any) available at the start of the simulation. If the station has no stock of charged batteries, this tab is left blank.



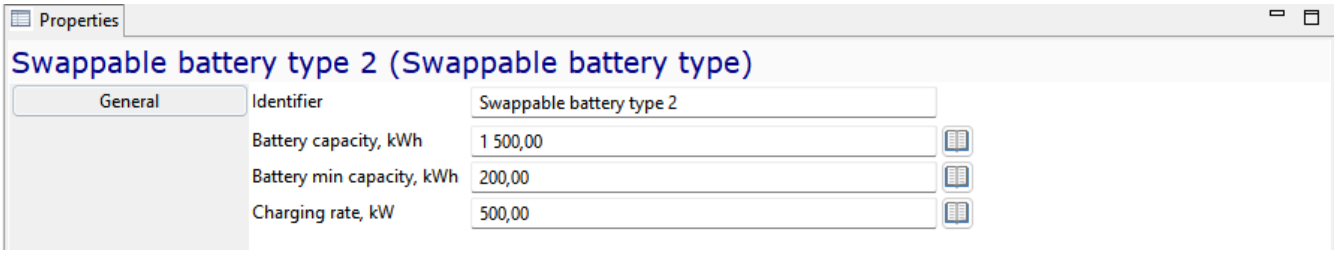
1.6.4. Fixed battery types



Fixed battery types are characterised by the following **General** properties:

- unique **Identifier**
- **Battery capacity, kWh** — the capacity of a fully charged battery
- **Battery min capacity, kWh** — the capacity value at which the equipment unit begins travelling to the recharging station
- **Charging rate, kW** — the charging power rate at which energy is transferred from the station to the battery per hour.

1.6.5. Swappable battery types



Swappable battery types are characterised by the following **General** properties:

- unique **Identifier**
- **Battery capacity, kWh** — the capacity of a fully charged battery
- **Battery min capacity, kWh** — the capacity value at which the equipment unit begins travelling to the recharging station

- **Charging rate, kW** — the charging power rate at which energy is transferred from the station to the battery per hour.

1.7. Ore

The **Ore** model tree element contains the following elements of an underground mine:

- Ore types
- Materials
- Stopes
- Excavation rules

1.7.1. Ore types

Ore - all minerals and empty rocks that are broken up during mining operations. The **Ore types** object tree element contains a list of all ore types that can be used for scheduling.

For each ore type, the following properties must be set:

- Unique **Identifier**
- **Ore category**: *production* or *development*.

1.7.2. Material

Material - a type of substance contained in the ore mass. The **Material** object tree element contains a list of all materials that can be used for scheduling.

The following properties must be set for each material:

- Unique **identifier**
- One of two logical **types**: *substance* or *empty rock*.

1.7.3. Stope

In MineTwin Underground terms, a stope is where the equipment performs operations. On the mine plan, the stope corresponds to the mine segment.

General parameters

The stope is characterized by the following main parameters:

- Unique **identifier**
- **Begin offset, m** – distance from the begin of the stope that was already developed at the start of planning/simulation, determines the working place in the stope
- **End offset, m** – distance from the beginning of the stope, determines the end of the stope for development. For example, the length of the stope is 60 meters, the begin offset is 20 meters, and the end offset is 55 meters. It means that the equipment will work in the stope only on the length from 20 to 55 m because 20 m is already finished, and the last 5 m is not available for work.
- **Density, t/m^3** - ore mass per unit volume minus the volume of pores, voids and cracks, in t/m^3
- **Fragmentation rate** - coefficient characterizing the increase in the volume of ore mass during destruction (blasting or cutting by continuous miner)
- **Priority** determines the sequence of mining operations, all other things being equal: mines with a lower priority will be planned earlier than mines with a higher priority
- **Unmined passage allowed** - the function is used in case of an increase in the section of the stope, provides through passage for permitted types of equipment
- **Ore type** - one of the possible types of ore mass in the scenario
- **Mine segment** - reference to the mine segment that corresponds to the stope
- **Mine segment length, m** is equal to the length of the mine segment, which corresponds to the stope
- **Mine area** - selection of the area to which the mine workings belong
- **Nearest suitable CDP** - the nearest overload point to the mine is displayed, where the mine mass can be sent from the mine
- **Nearest suitable ore pass** - the closest ore pass to the stope that can take on the ore type of the stope. The nearest suitable ore pass is determined automatically

- **Use allowed destinations** – when this feature is enabled, the rock mass from the workings will be transported only to the ore passes/CDP points specified in the **Outbound rules** in the order specified in the tab

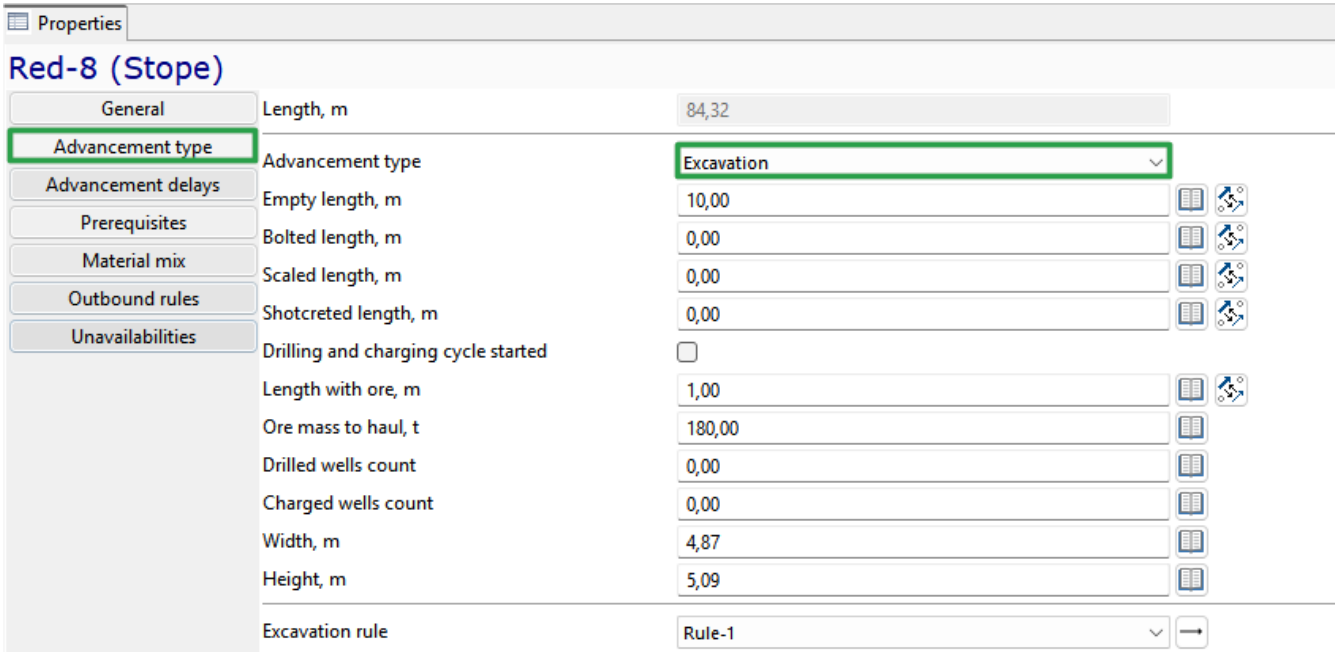
Advancement type

Parameters characterizing the way of the stope advancement and specifying the initial state of the stope at the moment of scheduling start must be necessarily specified for the stope.

First of all, you should set the advancement type of the stope. In MineTwin Underground, the following advancement types are developed:

- **Excavation** – front advancement of the stope with horizontal drilling
- **Cleaning** – stope advancement with vertical or diagonal drilling that is performed according to the rules set for the whole stope
- **Composite** – stope advancement with vertical or diagonal drilling that is performed according to the rules set for each drill ring
- **Backfill** – filling spent stopes with laying material after excavation of rock mass from them
- **Continuous** – cutting the ore with a continuous miner forward with subsequent ore excavation

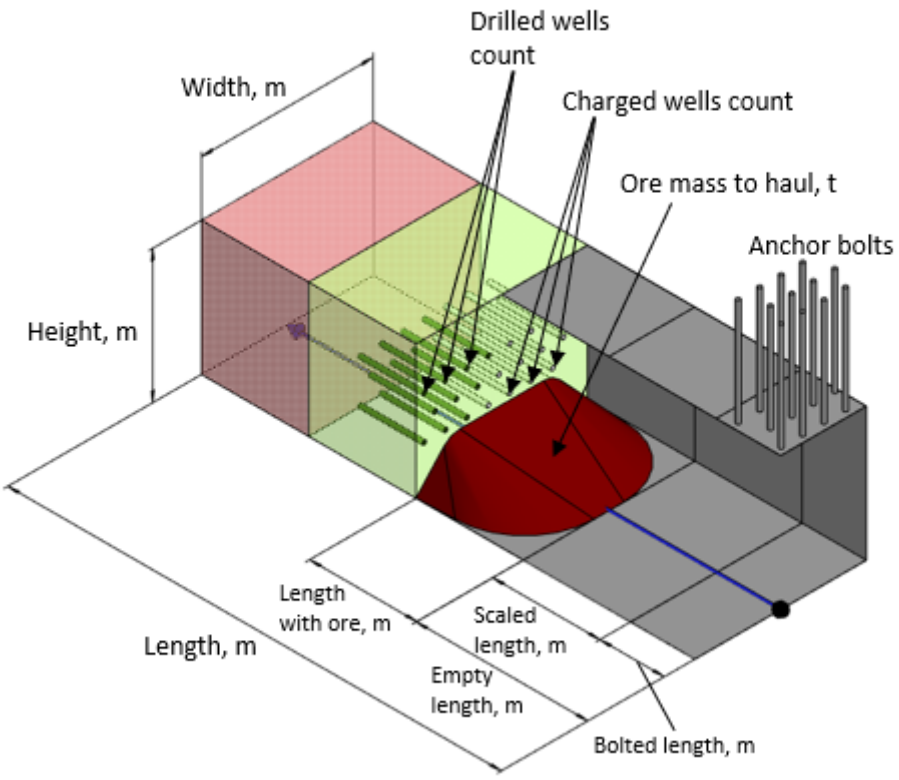
Excavation



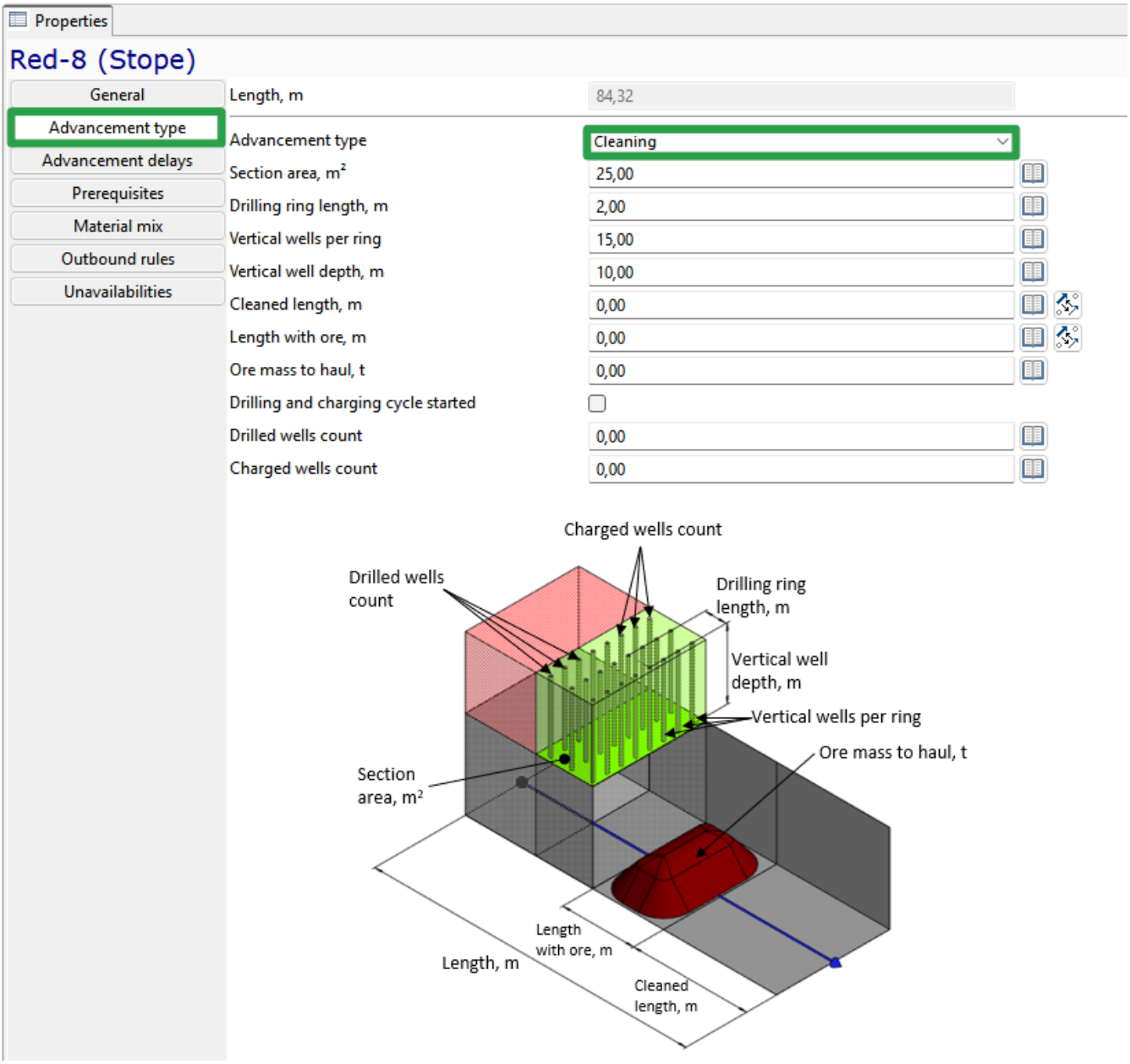
With the **Excavation** advancement type, the following parameters must be set for the stope:

- **Empty length, m** – the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- **Bolted length, m** – the length of the stope part where drilling, blasting and transportation of ore and roof bolting have already been fully completed
- **Scaled length** - the length of the part of the mine where drilling, breaking, transporting of the rock mass, and roof sheathing have been completed

- **Drilling and charging cycle started** - a parameter that indicates that drilling or charging is started but not yet completed in the stope
- **Do roofbolting** - a note about the need for roofbolting
- **Do scaling** - a note about the need for scaling
- **Length with ore, m** – the length of the stope part where drilling, charging and blasting of the ore mass are completed and the haulage of the ore mass is required
- **Ore mass to haul, t**
- **Drilled wells count**
- **Charged wells count**
- **Number of charged wells**
- **Width** of the stope, m
- **Height** of the stope, m
- **Excavation rule** – one of the possible rules containing additional information about the drilling rules (maximum drilling depth, number of wells per m^2 face, etc.).



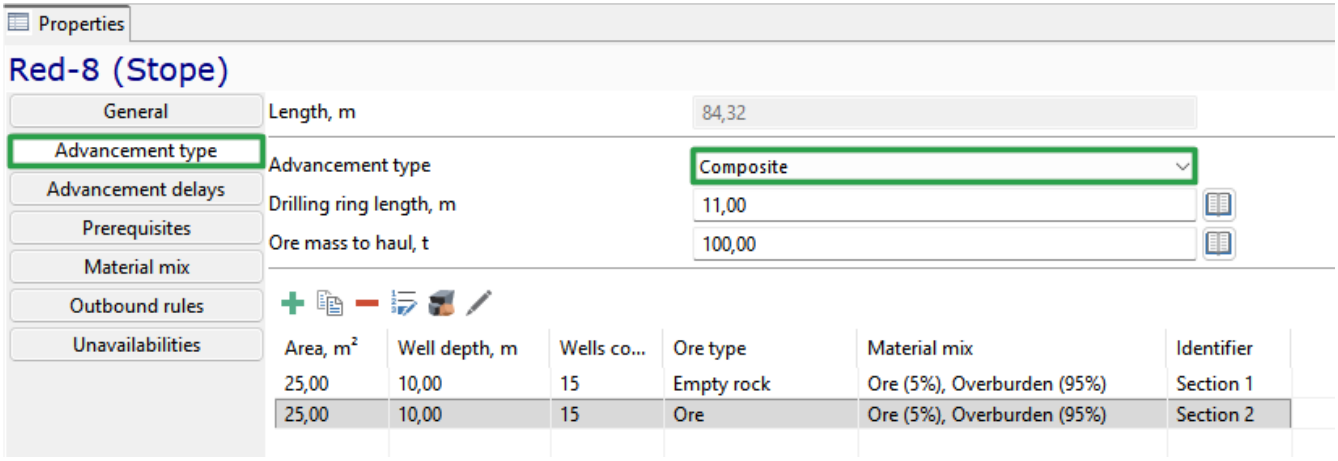
Cleaning



With the **Cleaning** advancement type, the following parameters must be set for the stope:

- **Section area, m^2** – average section area of the stope during cleaning
- **Drilling ring length, m** – distance between two drill rings
- **Number of vertical wells per one ring**
- **The average depth of a vertical well, m**
- **Cleaned length** – the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- **Length with ore, m** – the length of the stope part where drilling, charging and blasting of the ore mass are completed and the haulage of the ore mass is required
- **Drilling and charging cycle started** - a parameter that indicates that drilling or charging is started but not yet completed in the stope
- **Drilled wells count**
- **Charged wells count**

Composite



With the **Composite** advancement type, the following parameters must be set for the stope:

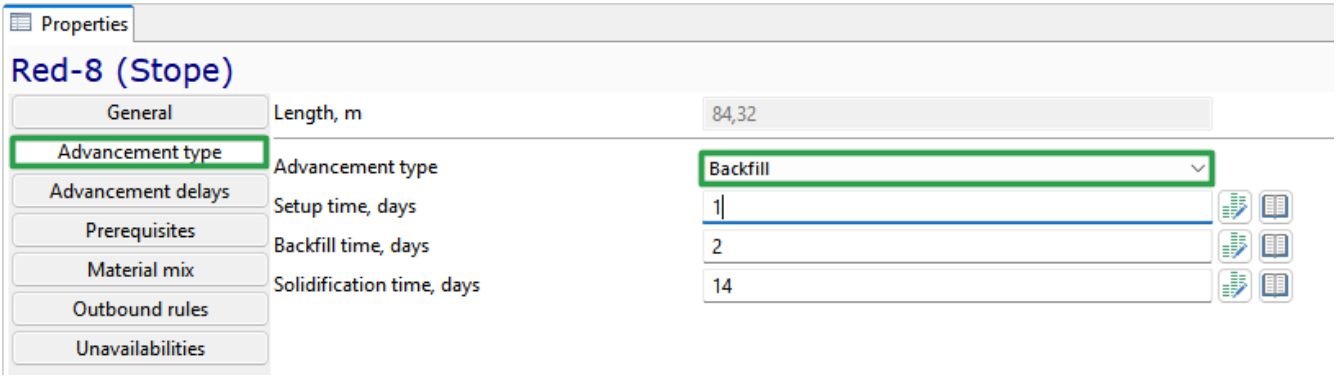
- **Drilling ring length, m** – distance between two drill rings
- **Ore mass to haul, t**
- For each drill ring must be set:
  - **Section area, m^2** – average section area of the stope during cleaning
  - **The average depth of a vertical well, m**
  - **Number of vertical wells**
  - **Ore type**
  - **Material mix**

The button  allows to automatically set the material mix for all drills, corresponding to the materials mix of the entire stope.

The button  allows to automatically set the ore type for all drills, corresponding to the ore type of the entire stope.

The button  allows us to edit the material mix of all drills of the stope in a separate window.

Backfill

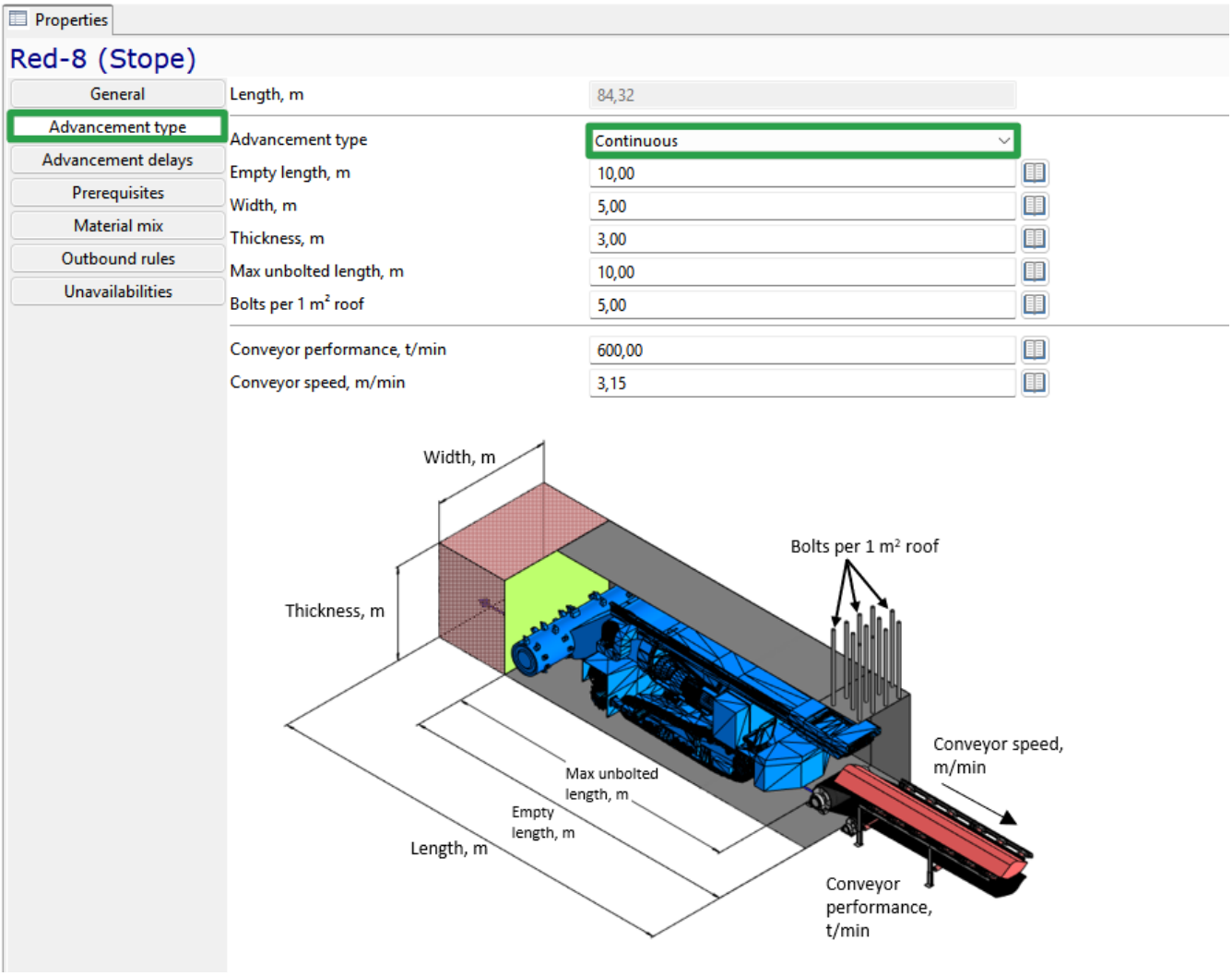


When choosing the test method **Backfill**, you must fill in the following parameters:

- **Setup time** in days

- **Backfill duration** in days
- **Solidification time** in days

Continuous



With the **Continuous** advancement type, the following parameters must be set for the stope:

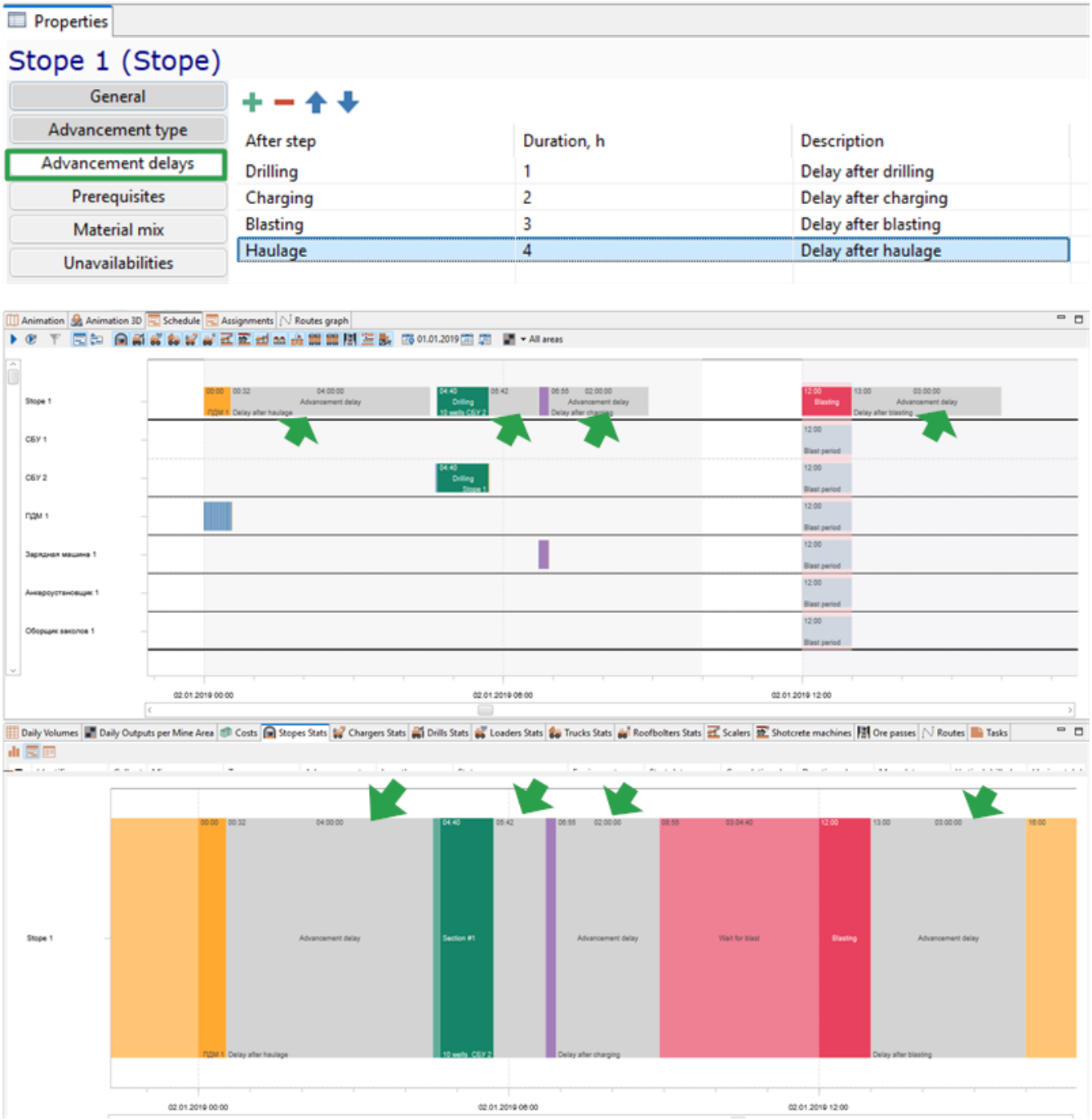
- **Empty length, m** – the length of the stope part where drilling, blasting and transportation of ore have already been fully completed
- **Width of the stope, m**
- **Thickness of ore mass cutting by a continuous miner, m**
- **Maximum unbolted length, m** – the maximum length of the stope on which the continuous miner is allowed to work without strengthening the stope roof
- **Number of bolts per m^2 of the stope roof**
- **Performance of the conveyor serving the stope, t /min**
- **Speed of the conveyor serving the stope, m/min**.

Advancement delays

In the block properties on the **Advancement delays** tab, you can set delays after each stage of stope

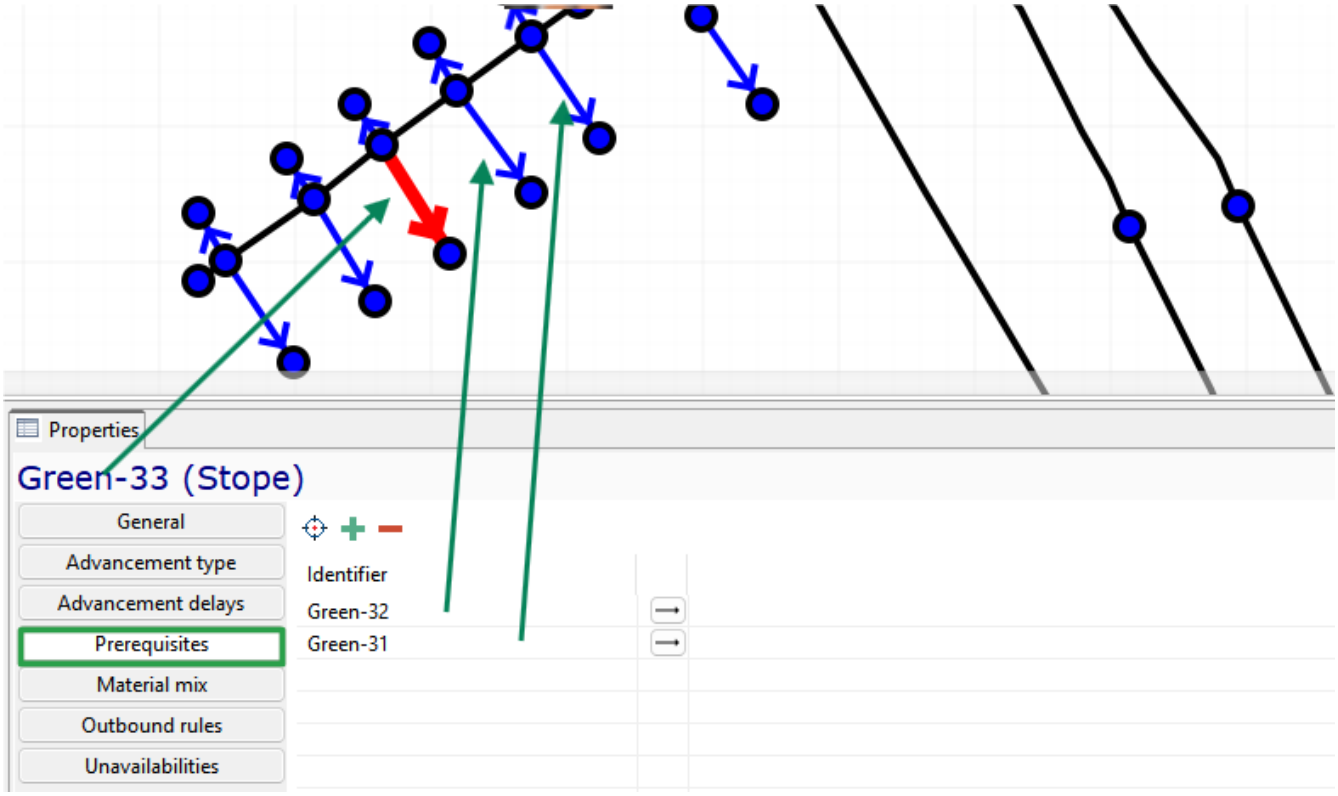
advancement. This feature is designed for modeling technological pauses before the start of the next stage of work (e.g., ventilation of the stope after blasting).

To create a delay, click the button, then in the row select the advancement step after which the delay will be added, specify its duration in hours, and add a description that will be displayed on the Gantt chart.



Prerequisites

MineTwin Underground allows us to set prerequisites between stopes, prohibiting the advancement of one stope until the stopes connected to it have been completely advanced.

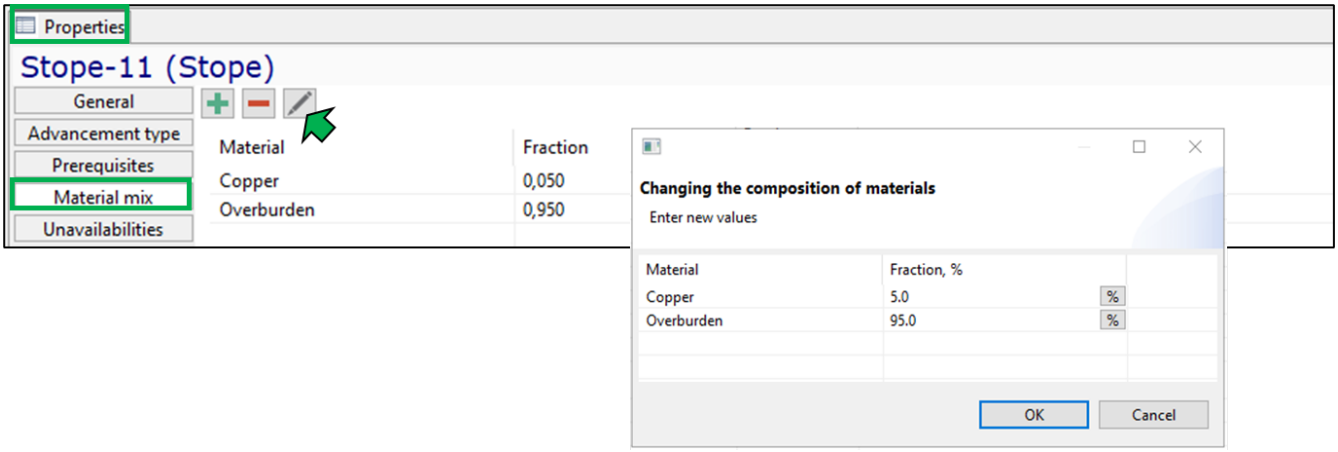


In the figure above, the advancement of Green-33 will be started only after the completion of the Green-32 and Green-31 advancement.

The button  allows you to select on a 2D map and add related stopes; the button  allows you to add related stopes from the list. The button  removes related stopes from the list.

Material mix

It is mandatory to fill in the Material mix in the stope.

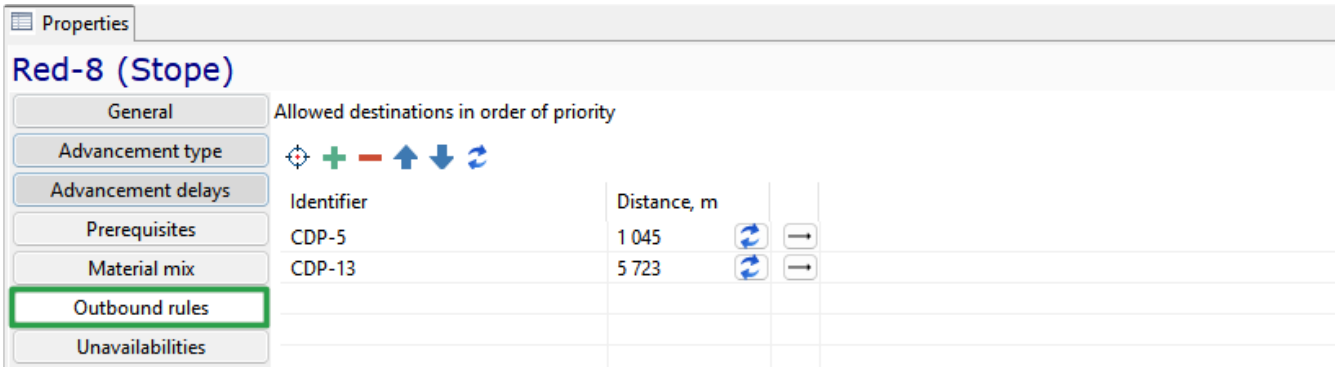


The buttons  allow to add/remove material to stope properties.

The button  allows us to edit the material mix in a separate window.

For each material, its proportion in the mix of the ore mass must be specified (from 0 to 1). The total fraction of the material mix should be equal to one.

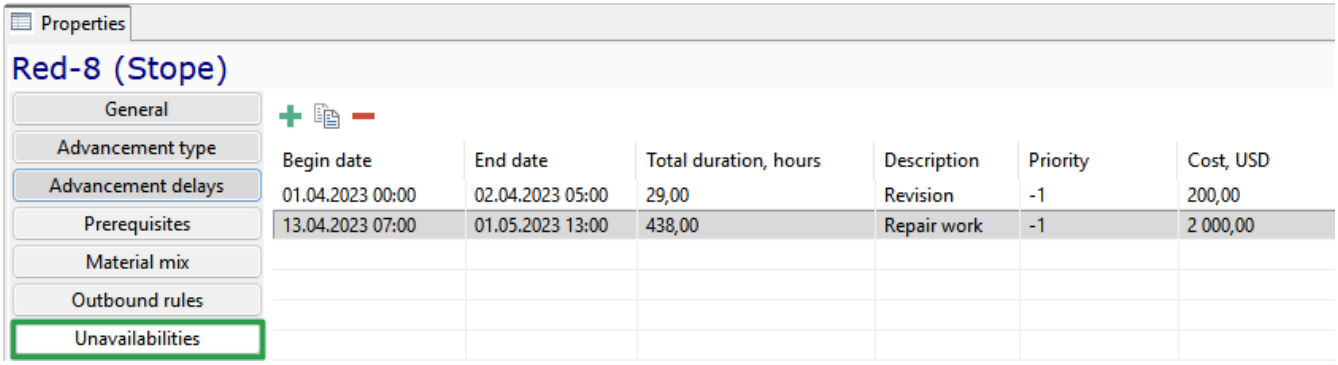
Outbound rules



On the **Outbound rules** tab, you can set a specific set of ore passes and CDPs. The button allows you to select export locations on the 2D map, the button allows you to add ore passes/overload points from the list, the export locations are removed from the list. The buttons allow you to swap lines., setting the order of testing. The button updates the values. The data in this tab is filled in if the function is selected. **Use only allowed destinations** on the **General** tab.

Unavailabilities

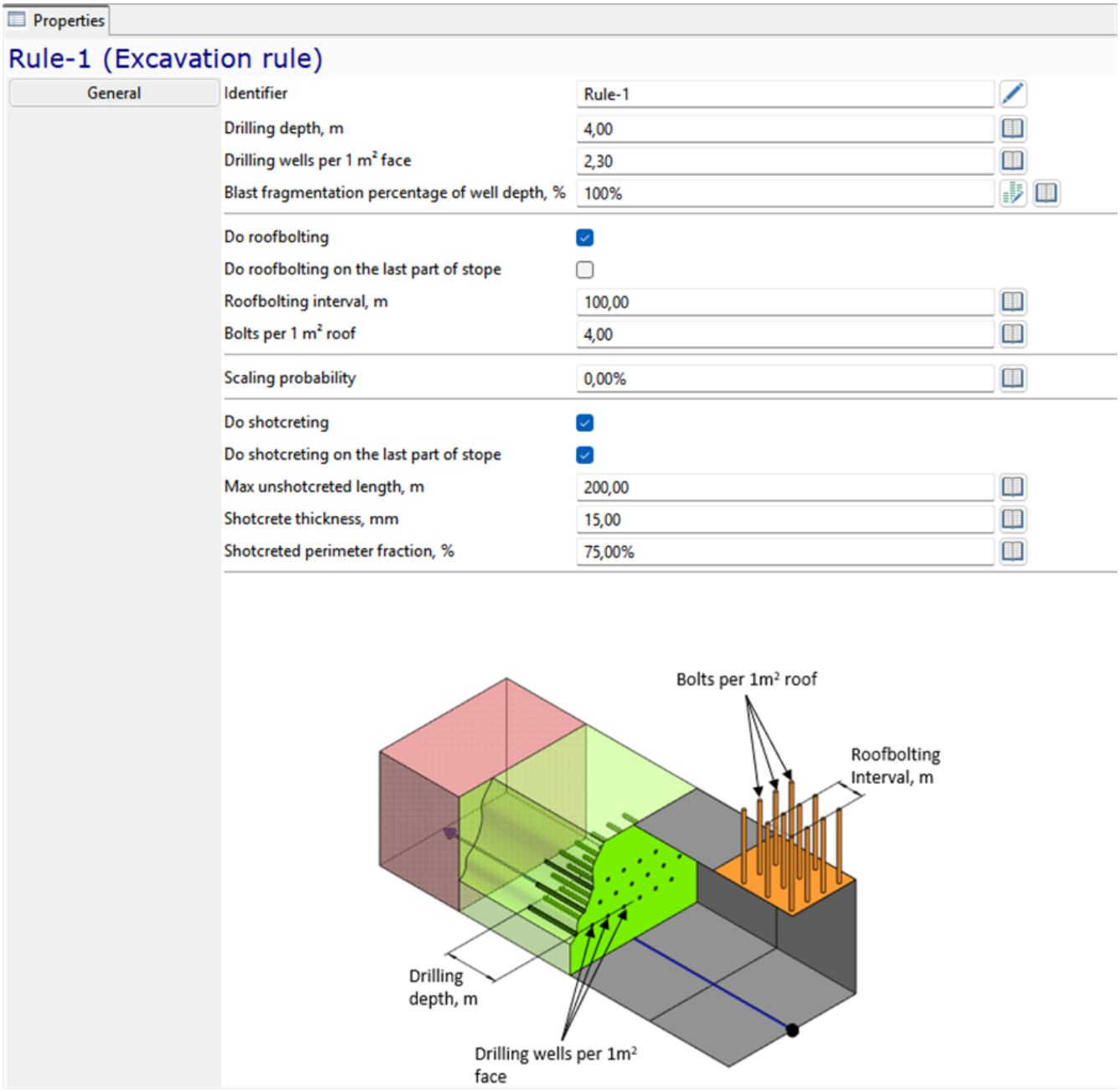
The periods of unavailability for advancement can be set for the stope. No equipment or transports will be scheduled in the stope during these periods.



The buttons allow you to add/remove stopes periods of unavailability.

1.7.4. Excavation rule

Excavation rule - an entity that contains the parameters of excavation in underground mines.



The excavation rule contains the following information about drilling:

- Unique **identifier** of the rule
- **Drilling depth** in meters
- **Blast fragmentation percentage of well depth, %** - percentage of the length of the borehole/well that is separated during blasting
- **Do roofbolting** - the function includes the operation of roofbolting with special equipment
- **Do roofbolting on the last part of stope** - the parameter allows you to set the support for the entire length of the workings If the checkbox is not selected, the support of the workings is not simulated after the last iteration of drilling and hauling
- **Roofbolting interval, m** - maximum length of a workpiece that can be developed without support
- **Bolts per 1 m^2 of the stope roof**
- **Scaling probability** - a parameter that determines the probability of modeling the scaling of the

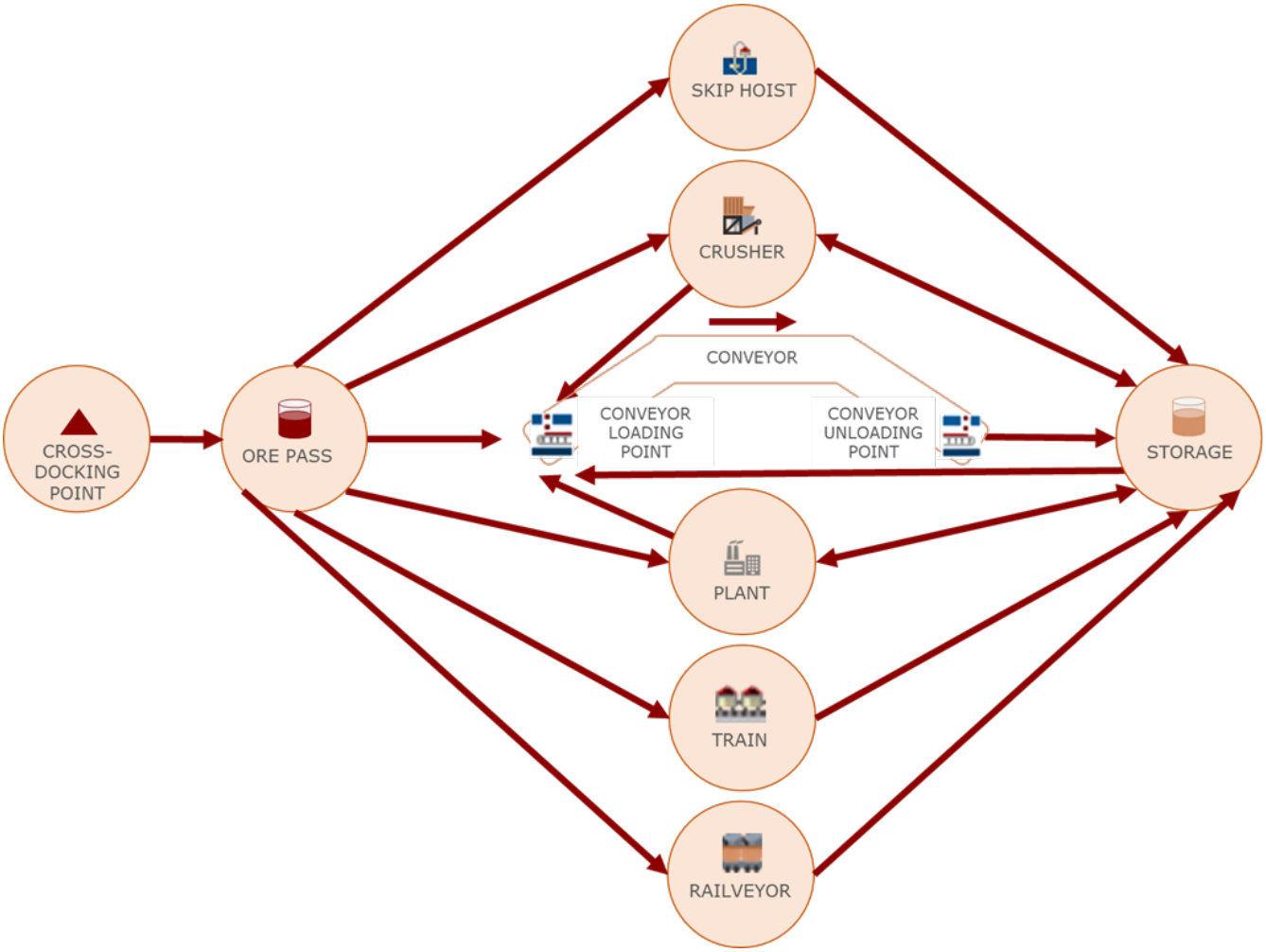
stope after the extraction of the rock mass. If set to 100%, the scaling of the stope will be modeled after each completion of the extraction of the rock mass. If set to 50%, then approximately half of the time, the self-propelled scaler will be modeled after the completion of the extraction, and half of the time, it will not be modeled

- **Do shotcreting** - the function includes in the production cycle an additional operation for applying a shotcrete mixture with special equipment. The operation is activated as the production is carried out to a predetermined **max unshotcreted length**
- **Do shotcreting on the last part of stope** - this parameter allows you to set the shotcrete for the entire length of the work. If the mark opposite the parameter is not set, then after the last iteration of the shipment of the blasted rock mass or the roofbolting of the stope, shotcrete is not simulated.
- **Max unshotcreted length, m** - the maximum length of the stope, upon reaching which, when carrying out/roofbolting the stope, the shotcrete operation is activated
- **Shotcrete thickness, mm** - thickness of the applied layer of shotcrete-concrete mixture
- **Shotcreted perimeter fraction, %** - Shotcrete may not be performed over the entire surface of the roof and sides of the stope, but, for example, only the roof or the roof and partially the sides. To determine the shotcrete area, the percentage of the production perimeter to which the mixture is applied is used. If the entire surface needs to be fixed, the parameter should be set to 100%. Then if the height of the work is 5 m, the width is 4 m, and the length without shotcrete is 10 m, then the area of the coating with the mixture will be (2*5+4)*10=140 m

The element of the tree of objects **Excavation rules** contains a list of all the rules that can be used in planning and simulation.

1.8. Parameters of the system elements ensuring the material flow

MineTwin Underground allows us to simulate the movement and processing of ore mass after its excavation from stopes. The mine elements serving the transportation and further processing of the ore mass can be combined into a connected system, the diagram of which is shown in the figure below.



The ore mass goes from the storages to the crushers, processing plants and blenders, and then goes back to the storages for further processing or is transported to dump areas.

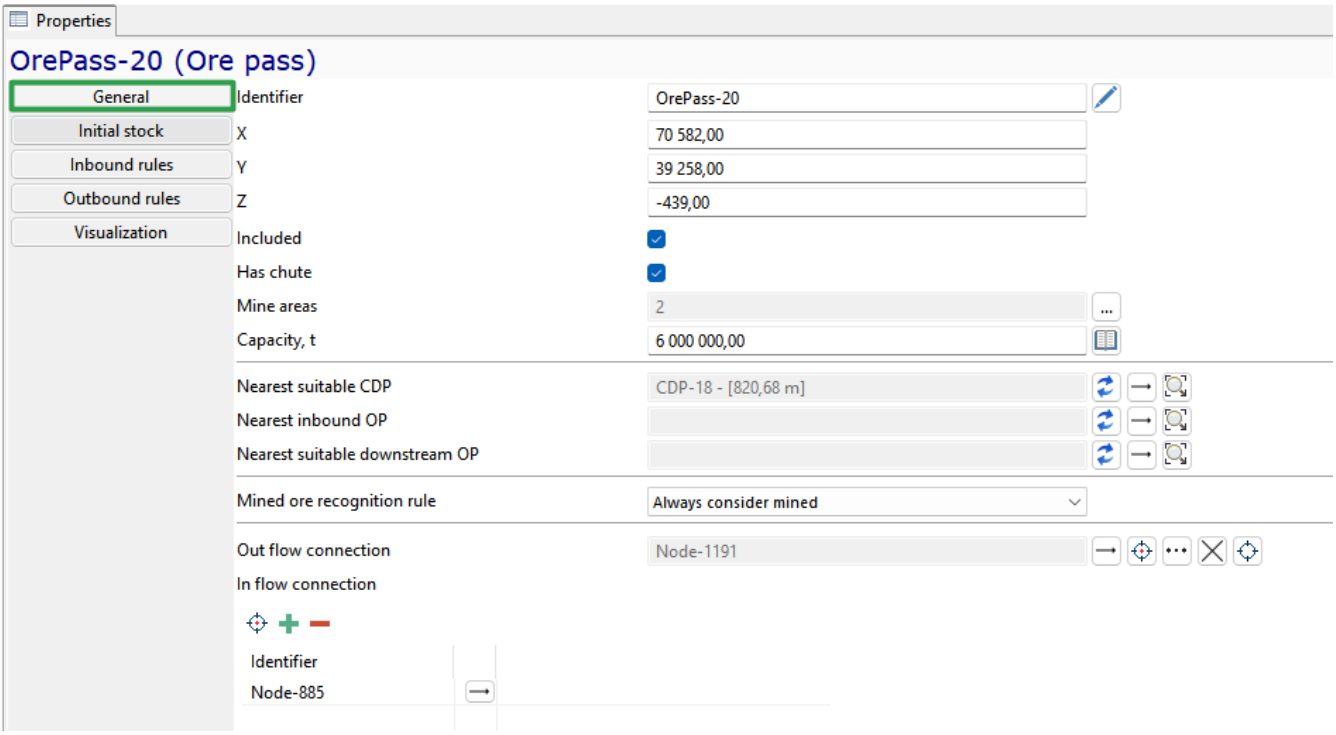
Elements of the system of transportation and processing ore mass are combined into a block of the model tree **Material flow**:

- Ore passes
- Storages
- Skip hoists
- Crushers
- Cross-dock points
- Conveyors
- Processing plants
- Railveyor routes

1.8.1. Ore passes

Ore pass - a part of the mine transport system involved in the movement of rock mass from the working area of the mine to the transport horizon.

General



The ore pass is characterized by the following main parameters:

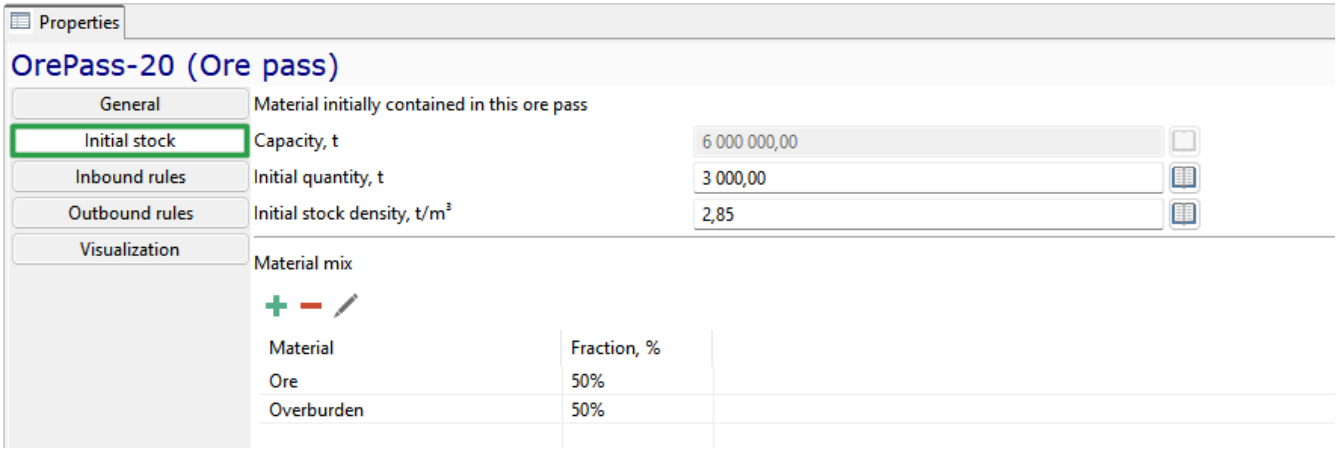
- Unique **identifier**
- **X**-, **Y**-and **Z**-coordinates
- **Included** - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- **Has chute** - the parameter indicates the method of loading the ore mass in the ore pass. If the ore pass is equipped with a chute, the ore mass is loaded directly into the dump truck without the use of loaders. If the ore pass is not equipped with a chute, the loading of the ore mass in the ore pass involves the use of loaders and one or more dump trucks, into which the loaders load the ore mass.
- **Mine areas** - an optional parameter. If a section is specified, only ore mass from stopes with the same section will be transported to the ore pass
- **Capacity, t** - the maximum amount of ore mass that a ore pass can hold
- **Max outbound rate, t/min** – rate of ore mass discharge from the ore pass to the conveyor
- **Max relative stock to accept transporters, %** – determines the level of ore pass filling at which the loader/dump truck stops transporting ore to the current ore pass and begins transporting it to alternative ore pass if any are available
- **Nearest suitable CDP** - the nearest overload point with the appropriate ore type is displayed, from which the ore mass can be received
- **Nearest inbound OP** - the nearest ore pass with a suitable ore type is displayed, from which the ore pass can receive ore
- **Nearest suitable downstream OP** - the nearest ore pass with a suitable ore type that can transport the ore from this ore pass

- **Mined ore recognitions rule** - rule for determining when the ore mass should be considered mined for statistics:
  - when the rule is selected *Consider mined if no outflow*, the ore mass that enters this ore pass will be considered mined only if the ore pass is the final storage location for the ore mass, i.e. it does not have an output node or connection to a conveyor, crusher, etc.
  - when the rule is selected *Always consider mined*, the ore mass that enters this ore pass will always be considered mined
  - If the rule is *Never consider mined*, the ore mass that enters the ore pass will never be considered mined (because it must be accounted for at a later stage of movement through the mine).
- **Output connection** is a reference to a transport network or equipment node where the ore is loaded from the ore pass. The ore can be loaded into the ore pass at multiple nodes in the mine field, including those located at different depths.
- The **Input connection** field contains a list of transport network nodes where vehicles can unload the ore into the ore pass.

The button allows you to select the desired minefield nodes on the 2D map, and the button allows you to add nodes from the list. The button removes minefield nodes from the list.

Initial stock

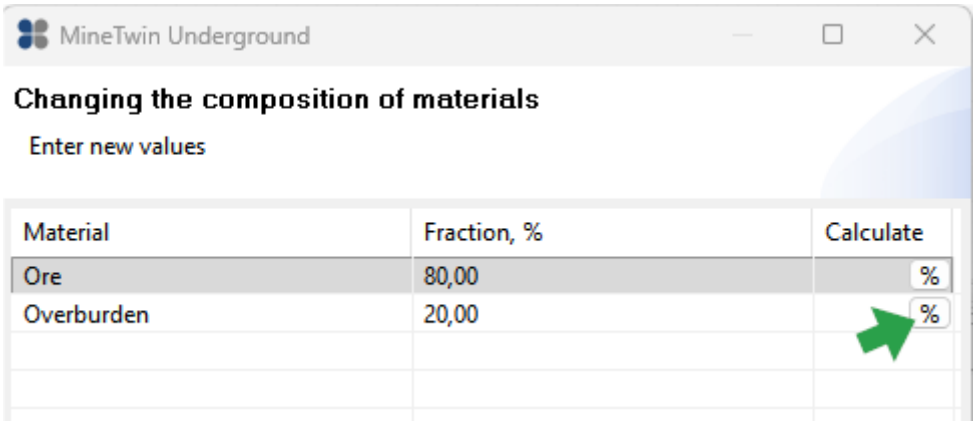
The **Initial stock** tab sets the characteristics of the rock mass in the ore pass at the beginning of the planning process. If the ore pass is empty at the beginning of the planning process, you do not need to fill in the tab.



If the ore pass contains a mass of ore at the beginning of the simulation, the tab displays:

- **Initial quantity, t** - in the ore pass
- **Initial density, t/m^3** - density of the ore mass in the ore pass
- **Material mix** - the percentage of rocks/ore in the initial reserve

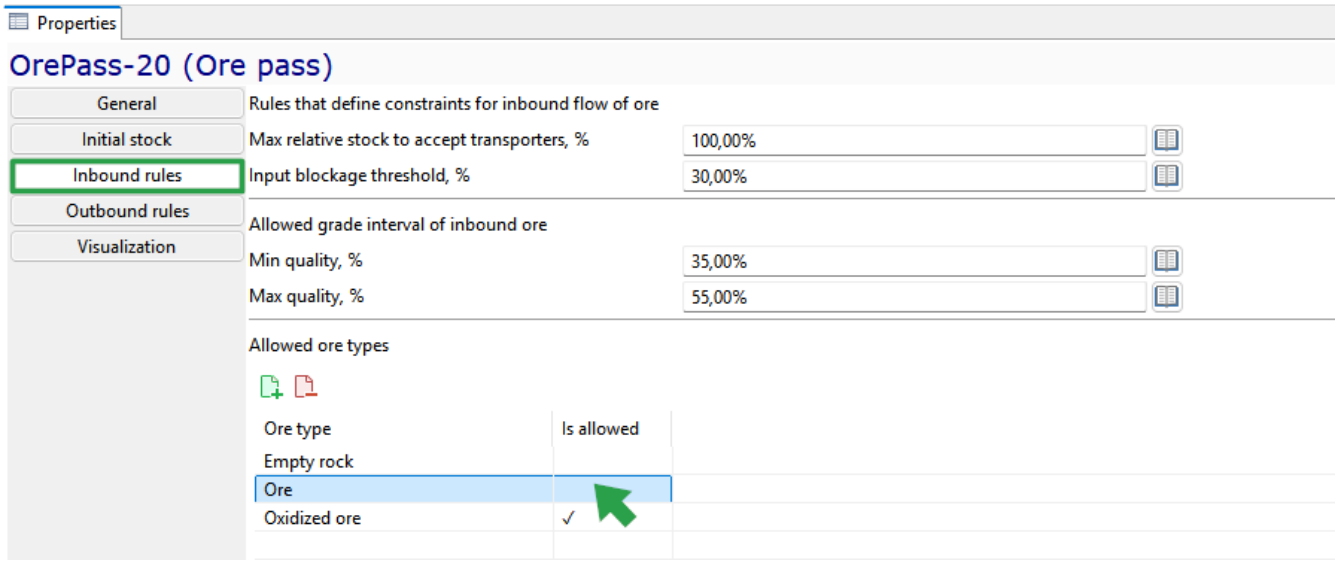
The button allows you to add rows to fill in the rock mass type. The button removes entries from the list. The button opens a window for filling in the rock composition at the beginning of the simulation.



If the cross-dock point is empty at the beginning of the planning process, the **Initial stock** tab is not filled in.

Inbound rules

The **Inbound rules** tab sets restrictions on the acceptance of ore into the ore pass.

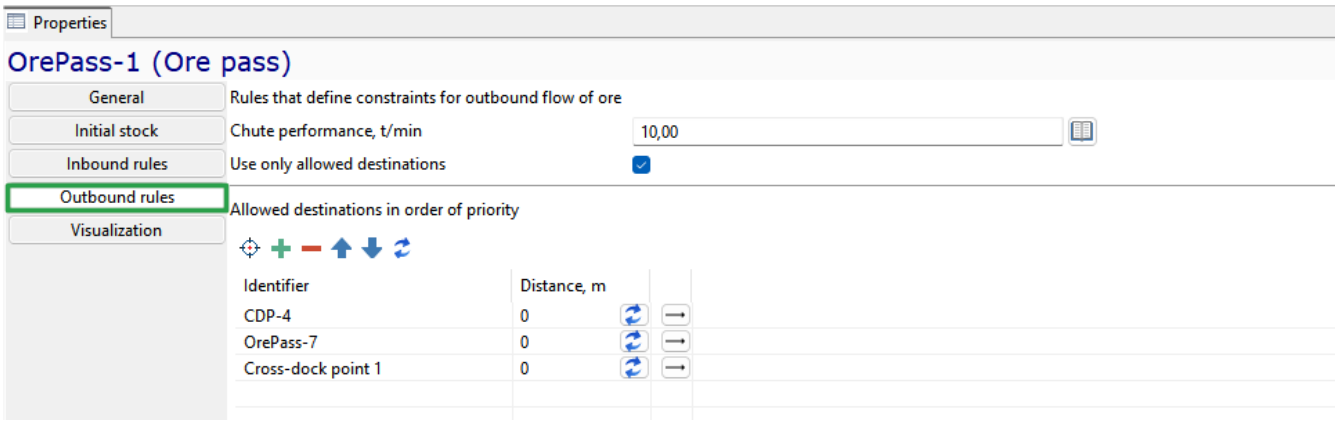


- **Maximum relative stock to accept transportrs, %** - determines the level of ore pass filling at which the truck/loader stops transporting ore to the given ore pass and starts transporting it to alternative ore passes, if any
- **Input blockage threshold, %**. For example, the ore pass is filled to its maximum capacity of 10,000 tons, and the conveyor that transports the ore to the ore pass stops (locks). The ore then flows to the crusher. The conveyor will only resume operation when the amount of ore in the ore pass reaches a specified level, such as 30%, which means that only 3,000 tons of ore remain in the ore pass.
- Allowed grade interval of inbound ore:
  - **Minimum ore quality, %** - minimum quality of rock mass that can be hauled to this ore pass
  - **Maximum ore quality, %** - maximum quality of rock mass that can be hauled to this ore pass
- **Allowed ore types** - selected manually by checking the box next to the required type of ore mass.

The buttons allow to select all ore types / remove all selections.

Outbound rules

The **Outbound rules** tab sets the parameters for unloading and further transportation of the ore from the ore pass.

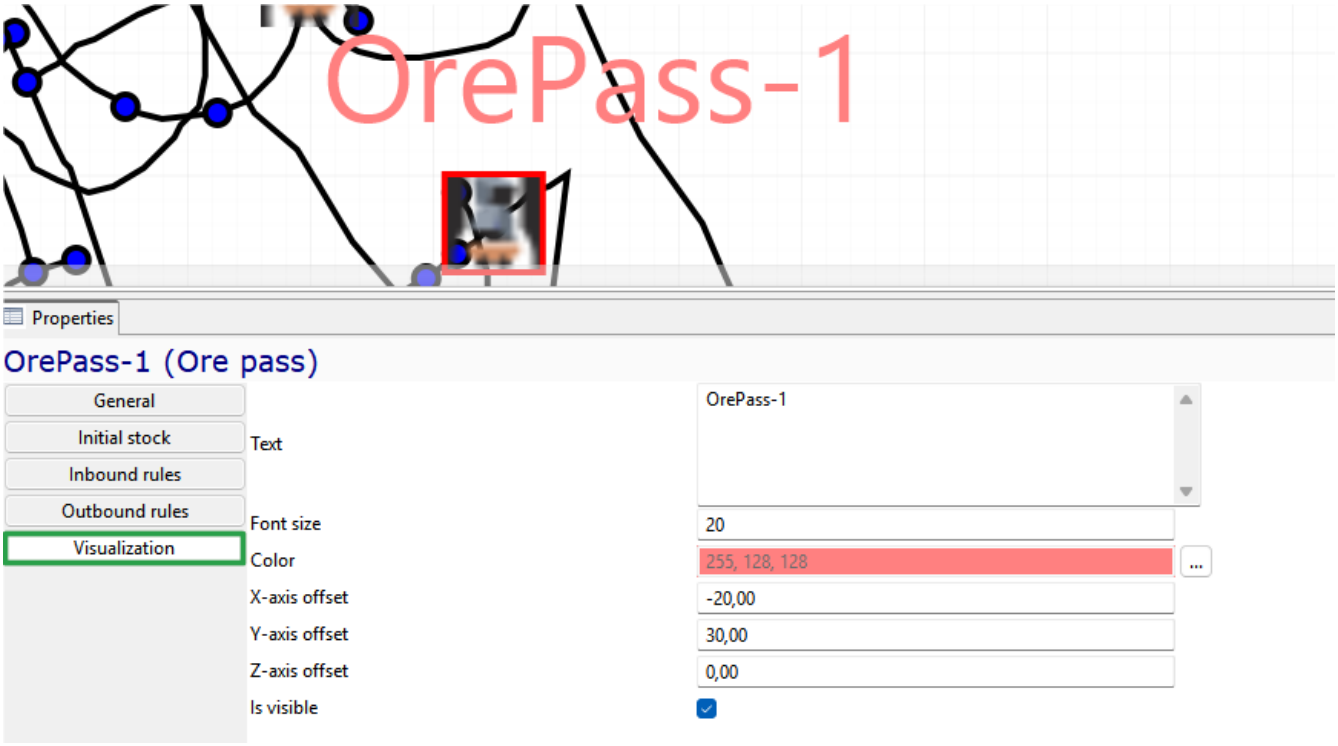


- **Chute perfomance, t/min** – ore unloading performance
- **Use only allowed destination** - when this function is enabled, the ore mass from the ore pass will be transported only to the ore passes specified in the **Allowed destination in order of priority** table
- The table below lists the **Allowed destinations in order of priority** – ore pass and/or cross-dock points (the top entry is the highest priority, and the bottom row is the lowest priority)

The button allows you to select the desired collection locations on the 2D map, while the button allows you to add objects from the list. The button removes entries from the list. The button allows you to go to the properties of the selected object. The button allows you to update the distance data to the corresponding objects.

Visualization

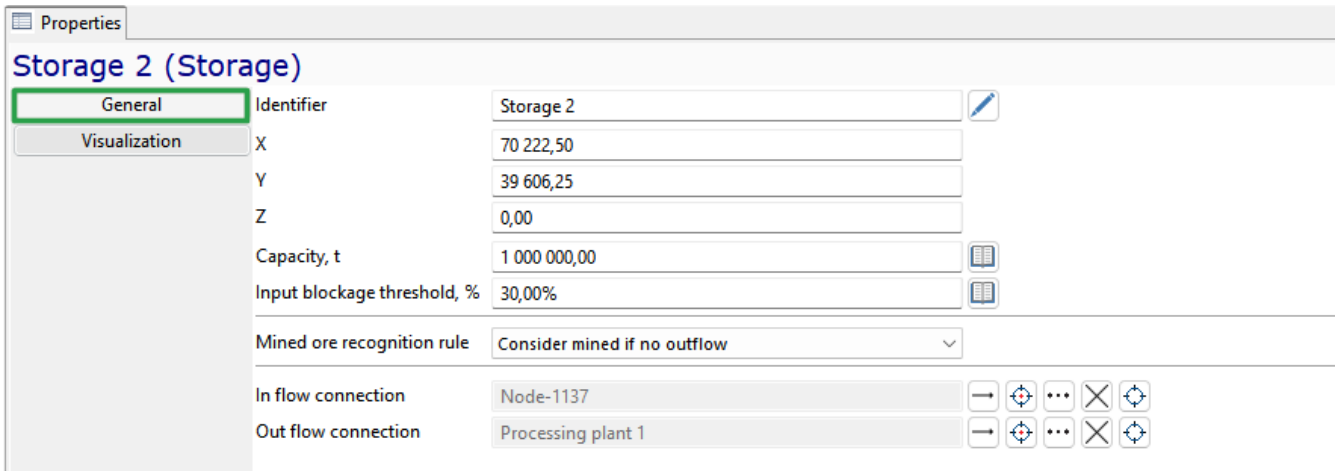
The **Visualization** tab is designed to create text labels for an object.



The tab allows you to set the font size and color, set the location of the label through offsets on the X, Y, and Z axes relative to the object icon on maps, and enable/disable visibility on 2D and 3D maps.

1.8.2. Storage

Storage - a place for intermediate storage of ore mass.



The storage is characterized by the following properties:

- Unique **identifier**
- **X**-, **Y**- and **Z**-coordinates
- **Capasity, t** - the maximum quantity of ore that can accommodate the storage
- **Input blockage threshold, %** - the level of fullness for resuming the operation of the element of the in-line transport technology included in it, %. For example, the storage is filled to the maximum capacity of 10,000t, and the conveyor transporting the rock mass into it stops (is blocked). From the storage, the rock mass enters the crusher. The conveyor will resume its

operation only when the amount of rock mass in the storage drops to a given level, for example, 30%, i.e. when only 3,000t remains in the storage.

- **In flow connector** - reference to the equipment unit from which the ore mass enters the storage: crusher, conveyor, processing plant, or skip hoist
- **Outflow connector** - a reference to the equipment unit to which the ore mass enters from the storage: rusher, processing plant, or skip hoist
- **Mined ore recognitions rule** - rule for determining when the rock mass should be considered mined for statistics:
  - when the rule is selected *Consider mined if no outflow*, The rock mass that enters this storage facility will be considered mined only if the storage facility is the final location for the rock mass, i.e., it does not have an output connection to a conveyor, crusher, etc.
  - when the rule is selected *Always consider mined*, the rock mass that enters this storage will always be considered mined
  - If the rule is *Never consider mined*, the rock mass that enters the storage will never be considered mined (because it must be accounted for at a later stage of movement through the mine).

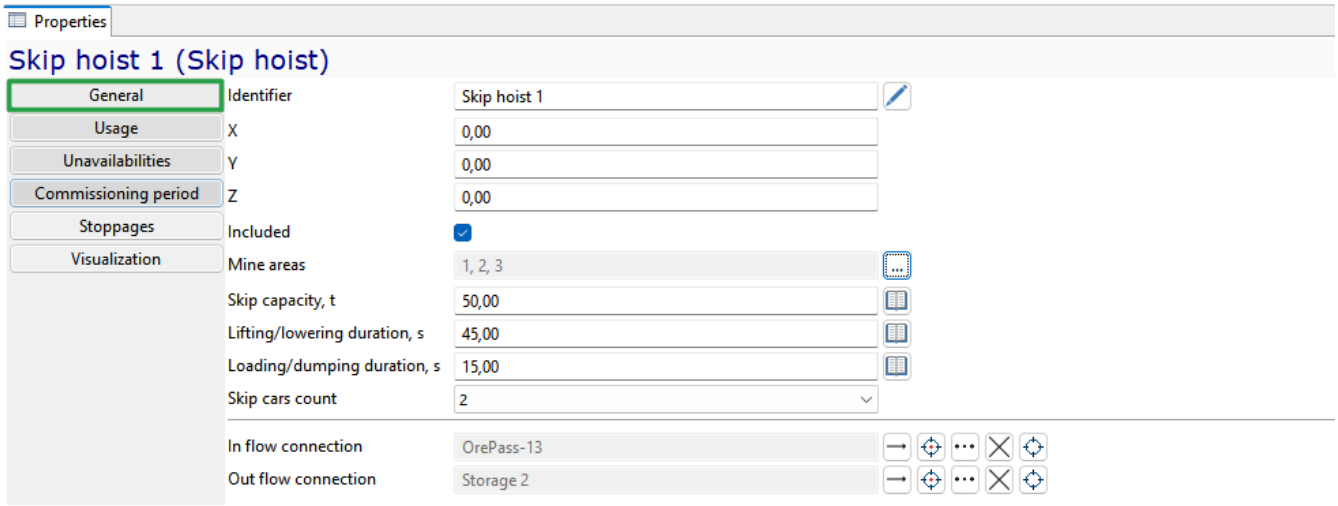
The **Visualization** tab is designed to create text labels for an object.

1.8.3. Skip hoist

Skip hoist - a piece of equipment designed to lift the ore mass from an underground mine to the surface of the earth.

General

A skip hoist consists of a pair of skip trolleys (skips). In the process of lifting the ore mass, the ore is alternately loaded into one skip and transported to the top. While one skip is being raised, the other skip is lowered.



The skip hoist is characterized by the following main parameters:

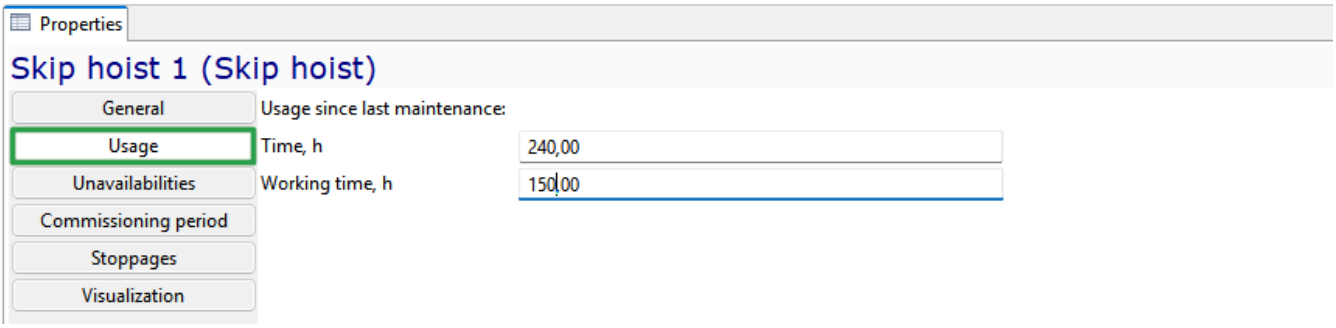
- Unique **identifier**

- **X**-, **Y**- and **Z**-coordinates
- **Included** - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- **Mine area** to which the equipment unit is assigned
- **Scip capacity, t** – capacity of skip trolley in tones
- **Lifting/lowering duration, s** - the duration of lifting and lowering of skip trolley (as the processes of lifting one skip and lowering the other occur in parallel, the duration of these cycles is the same), in seconds
- **Loading/dumping duration, s** - the duration of loading and unloading of one skip trolley (as the processes of loading one skip and unloading another occur in parallel, the duration of these cycles is the same), in seconds
- **Skip cars count**: one or two
- **In flow connector** - reference to the ore pass from which the ore mass enters the skip hoist
- **Outflow connector** - reference to the storage to which the ore mass enters from the skip hoist

Usage

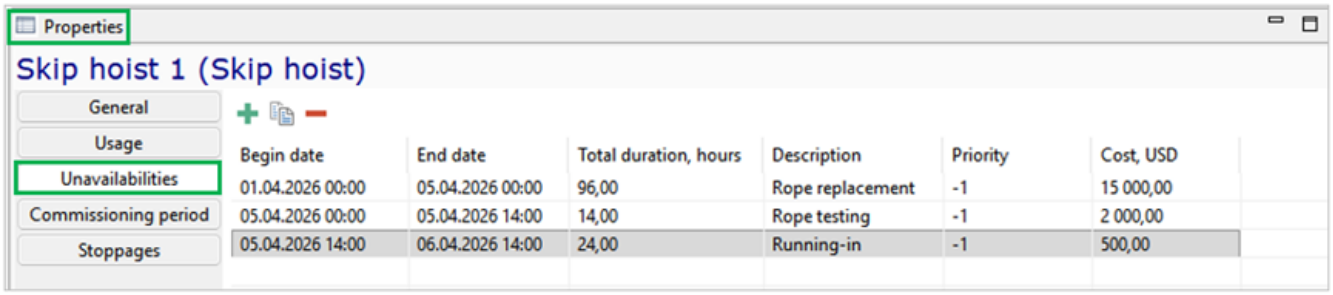
On the Usage tab, the initial state of the parameters related to its maintenance by run-hours is set in the Material flow group:

- Initial run-hours for the **Time** parameter – the total time that the equipment unit has worked at the start of planning/simulation
- Initial run-hours for the **Working time** parameter – the number of motor hours (hours of motor operation during movement, loading, and unloading) that the equipment unit has worked at the start of planning/simulation



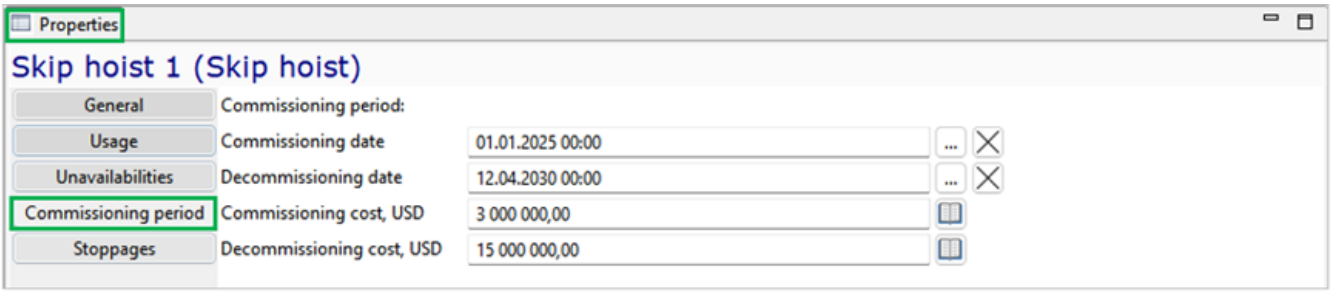
Unavailabilities

For equipment in the **Material flow** group, you can also set planned periods of inaccessibility on the **Unavailabilities** tab.



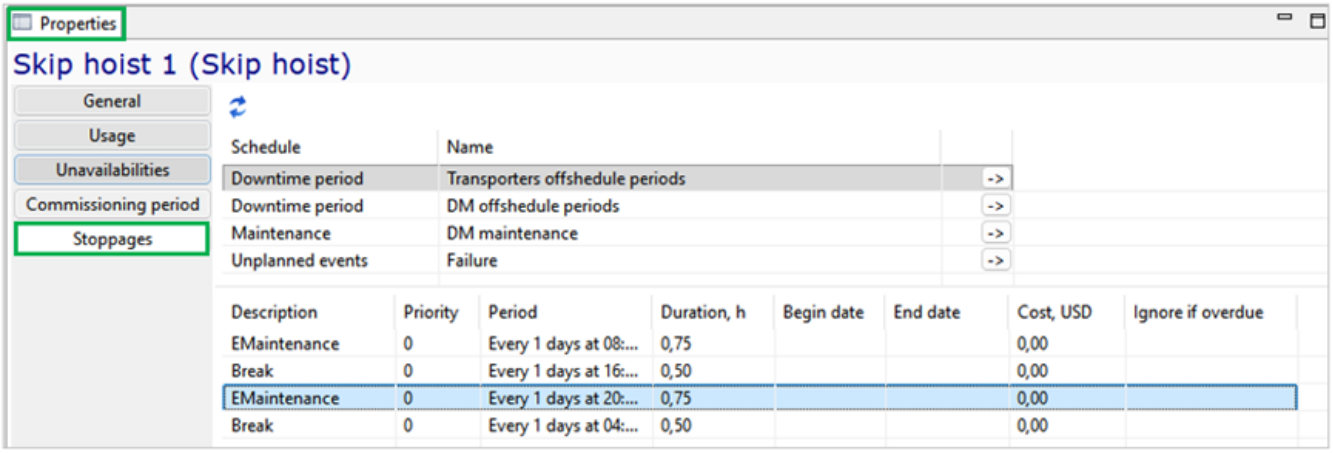
Comissioning period

In the **Comissioning period** tab, the dates of commissioning and decommissioning of the equipment unit can be set, as well as the costs of commissioning (purchase) and decommissioning (disposal). Before the date of commissioning / after the date of decommissioning, the equipment unit is not included in the planning/simulation.



Stoppages

The **Stoppages** tab is used to view the list of scheduled and random downtime events specified in the Schedule object tree group.

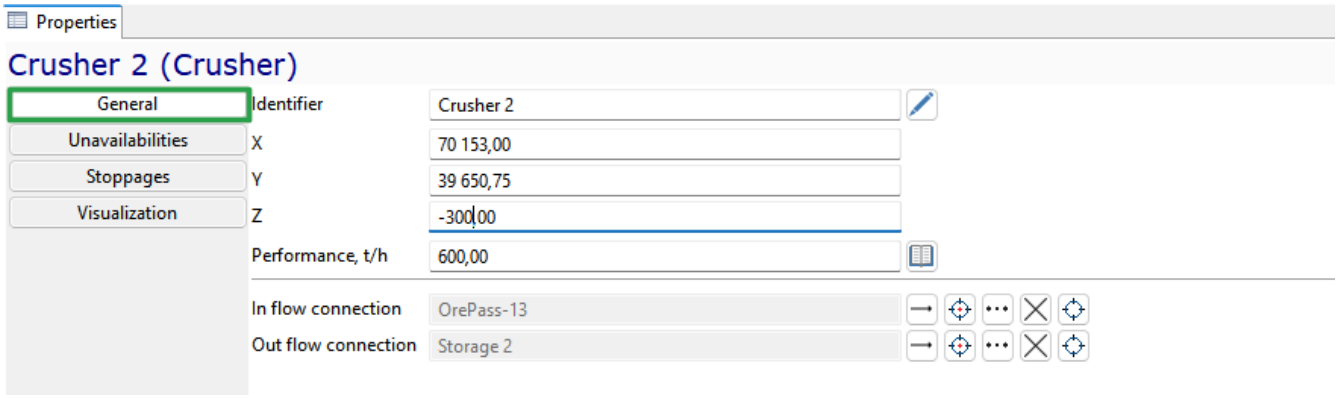


Visualization

The **Visualization** tab is designed to create text labels for an object.

1.8.4. Crusher

Crusher - a piece of equipment for crushing – using mechanical impact on the rock to destroy it.



The crusher is characterized by the following main parameters:

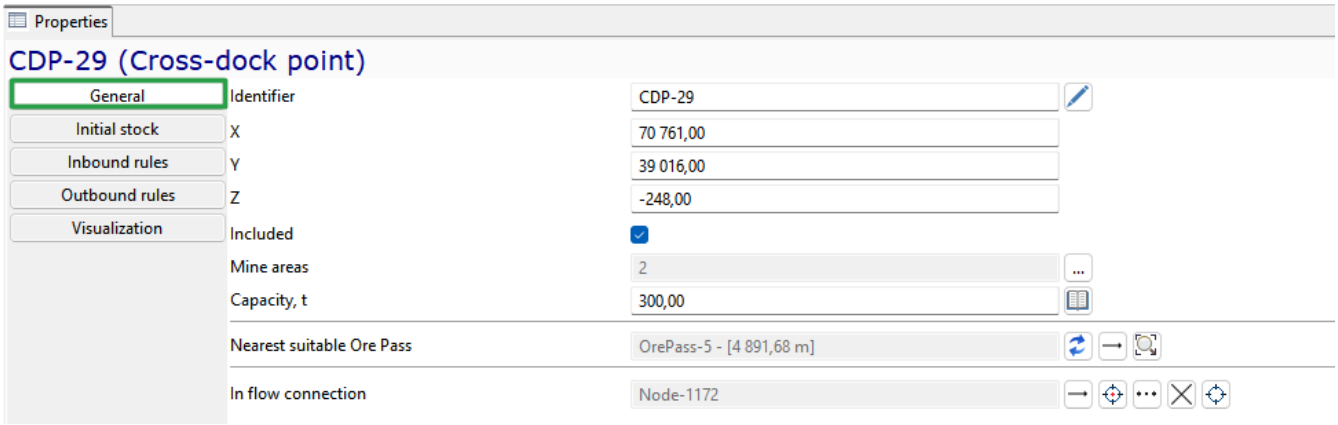
- Unique **identifier**
- **X**-, **Y**- and **Z**-coordinates
- **Performance, t/h**
- **In flow connector** - reference to the equipment unit from which the ore mass enters the crusher: storage or conveyor
- **Out flow connector** - reference to the equipment unit to which the ore mass enters from the crusher: storage, conveyor or processing plant.

You can set periods of **Unavailability** for the crusher. The **Stoppages** tab provides information about all planned and probabilistic downtime periods, with a button that allows you to navigate to the corresponding editing window in the **Schedules** group.The **Visualization** tab is designed to create text labels for an object.

1.8.5. Cross-dock point

Cross-dock point - a mine node where equipment stops while waiting for loaders and trucks, and the ore mass is reloaded from loaders to trucks.

General



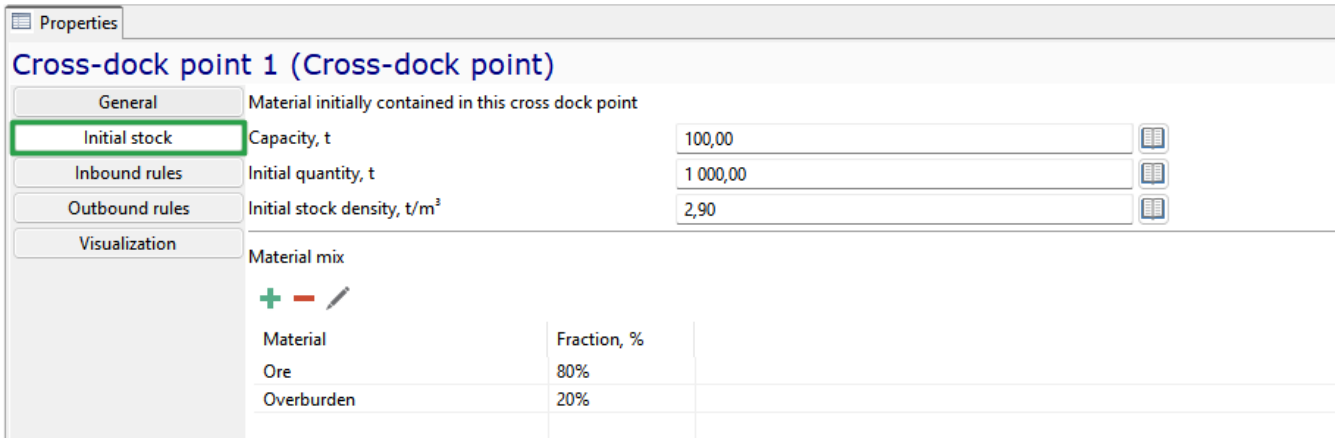
The cross-dock point is characterized by the following **General** parameters:

- Unique **identifier**
- **X**-, **Y**-and **Z**-coordinates

- **Included** - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- **Mine areas** to which the equipment unit is assigned
- **Capasity, t** - the maximum amount of rock mass that a cross-dock point can hold
- **Nearest suitable ore pass** - the closest ore pass to the cross-dock point that can take on the ore type of the cross-dock point. The nearest suitable ore pass is determined automatically
- **In flow connection** - link to the transport network node from which the download will be performed

Initial stock

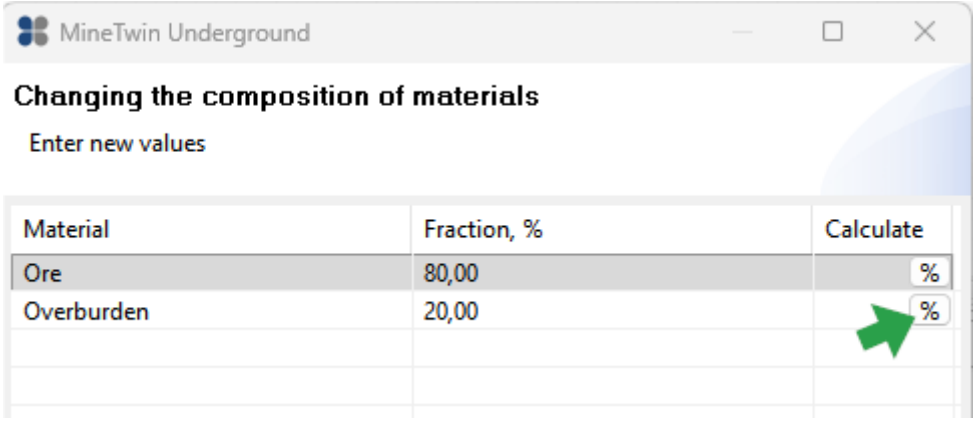
The **Initial stock** tab fills in the characteristics of the ore mass that is at the cross-dock point at the beginning of the model period.



The tab displays the total capacity of the cross-dock point in tons, as well as data that is filled in when the volume of ore mass at the transfer point is available at the start of planning:

- **Initial quantity, t** - amount of ore mass in the cross-dock point
- **Initial stock density, t/m^3**, in the cross-dock point
- **Material mix** - the percentage of rocks/ore in the initial reserve

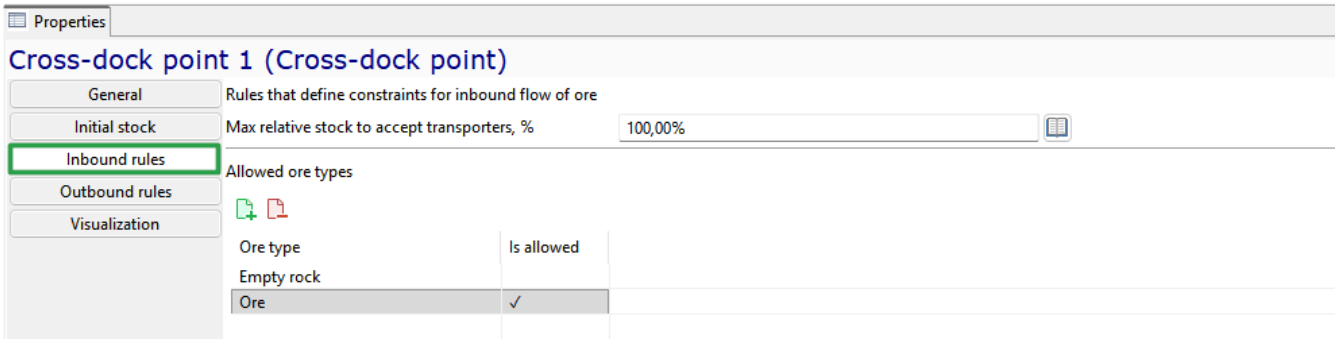
The ✚ button allows you to add rows to fill in the rock mass type. The ▬ button removes entries from the list. The ✎ button opens a window for filling in the rock composition at the beginning of the simulation.



If the cross-dock point is empty at the beginning of the planning process, the **Initial stock** tab is not filled in.

Inbound rules

The **Inbound rules** tab sets restrictions on the acceptance of ore mass at the cross-dock point.

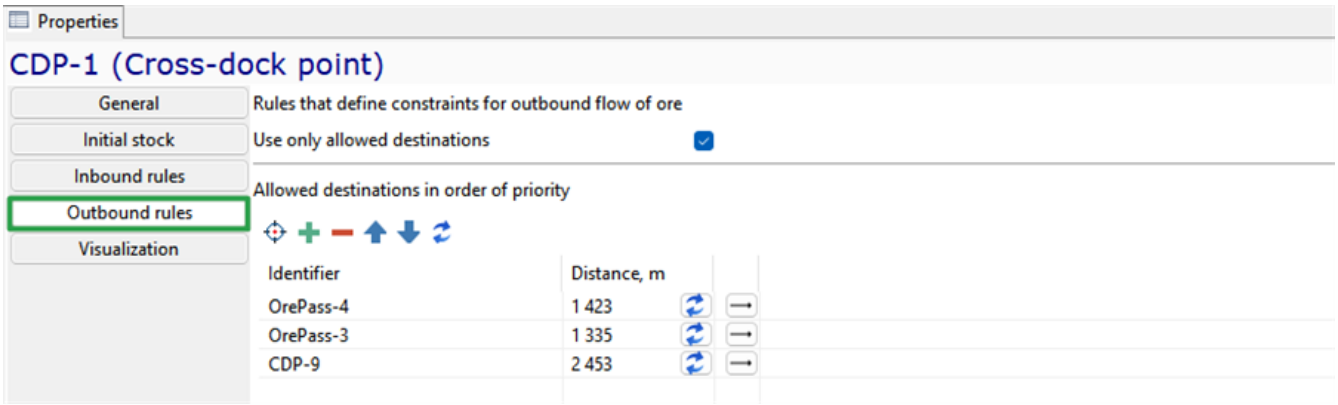


- **Max relative stock to accept transporters, %** – determines the level of ore cross-dock point filling at which the loader/dump truck stops transporting ore to the current cross-dock point and begins transporting it to alternative cross-dock point if any are available
- **Allowed ore types** - selected manually by checking the box next to the required type of ore mass.

The buttons  allow to select all ore types / remove all selections.

Outbound rules

The **Outbound rules** tab sets the parameters for unloading and further transportation of the ore from the cross-dock point.



- **Use only allowed destination** - when this function is enabled, the ore mass from the cross-dock point will be transported only to the cross-dock pointes specified in the **Allowed destination in order of priority** table
- The table below lists the **Allowed destinations in order of priority** – ore pass and/or cross-dock points (the top entry is the highest priority, and the bottom row is the lowest priority)

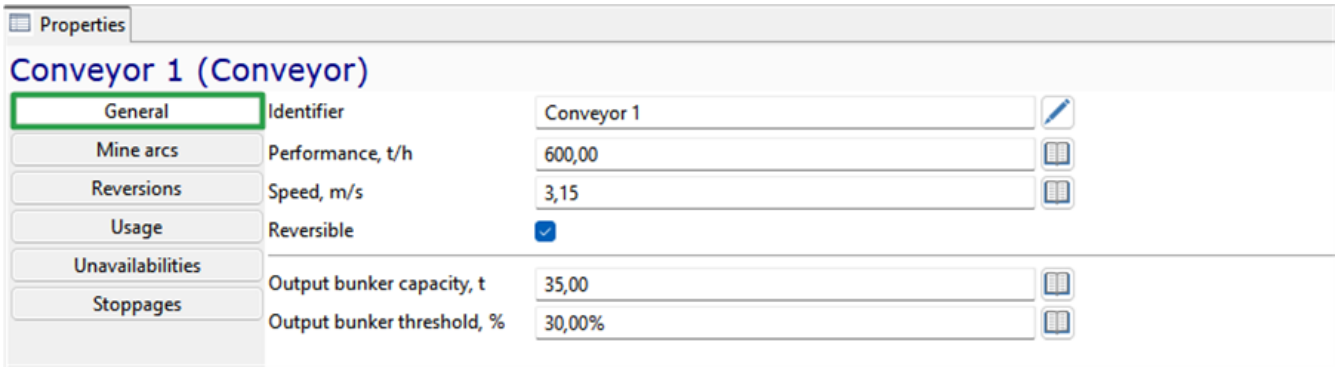
The  button allows you to select the desired collection locations on the 2D map, while the  button allows you to add objects from the list. The button removes entries from the list. The button allows you to go to the properties of the selected object. The  button allows you to update the distance data to the corresponding objects.

Visualization

The **Visualization** tab is designed to create text labels for an object.

1.8.6. Conveyor

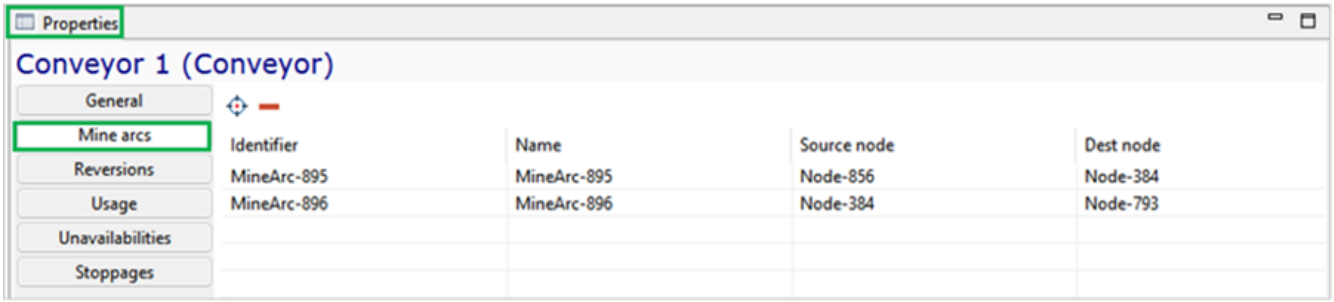
Conveyor - a continuous-action mechanism for transporting ore mass. The ore mass can enter the conveyor from storages, crushers and processing plants and is transported to storages, crushers and processing plants.



The conveyor is characterized by the following main parameters:

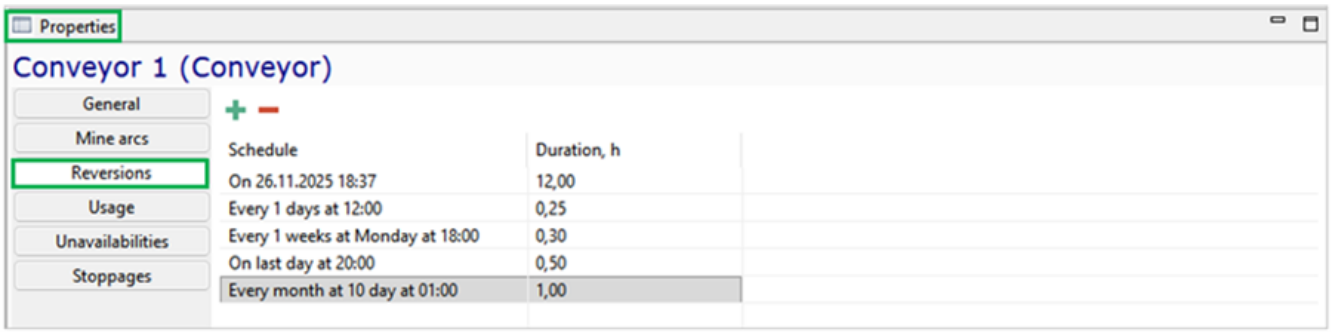
- Unique **identifier**
- **Performance** of ore mass transportation in tons per minute
- **Conveyor belt speed, m/min**
- **Reversible** - setting a mark next to the parameter enables the tape to move in the opposite direction. The schedule of the periods is set on the **Reversions**
- **Output bunker capacity, t** - is a technical parameter that is used to prevent the simulation from stopping with an error. In reality, an overflow conveyor is an emergency situation. In the simulation, the excess rock mass enters the internal virtual buffer, and after it fills up to the set value, the conveyor will stop (block). This can happen if the rock mass enters one conveyor from several conveyors, or if the underlying conveyor stops for a break or breakdown.
- **Output bunker threshold, %** - is the percentage of occupancy of the internal buffer at which the conveyor resumes operation after an emergency stop

One conveyor can consist of several segments. In the **Mine arcs** tab, you can set the list of mine arcs of the conveyor that make up the given conveyor.



Mine arcs are added by selecting them on the minefield using the button  and removed from the conveyor using the button  .

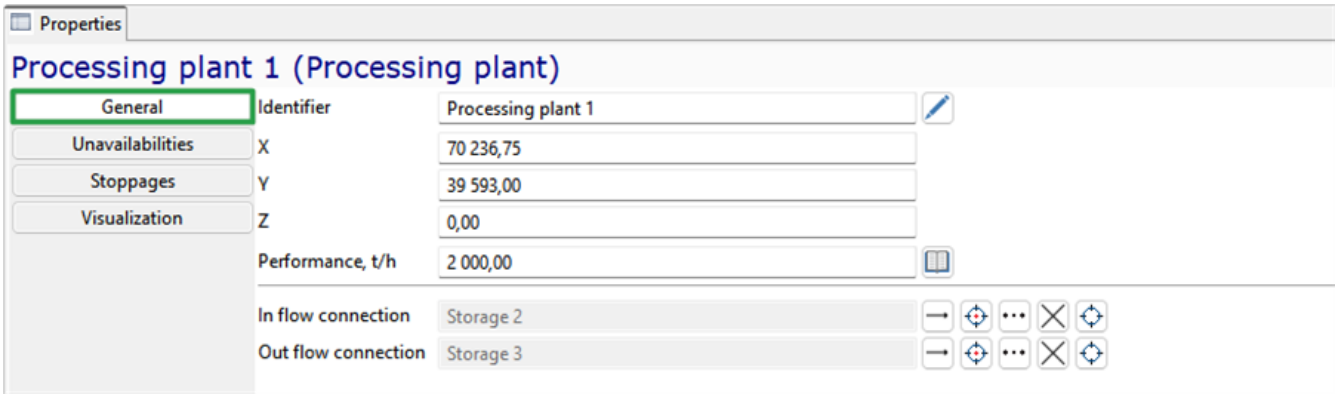
The Reversions tab sets the periods of time when the conveyor operates in reverse mode (in the opposite direction).



In the conveyor properties, the initial **Usage** and periods of **Unavailability** can be set in the corresponding tabs. The **Stoppages** tab provides information about all planned and probabilistic downtime periods, with a button that allows you to navigate to the corresponding editing window in the Schedules group.

1.8.7. Processing plant

Processing plant - a mining enterprise for the primary processing of ore mass to obtain technically valuable products suitable for industrial use.



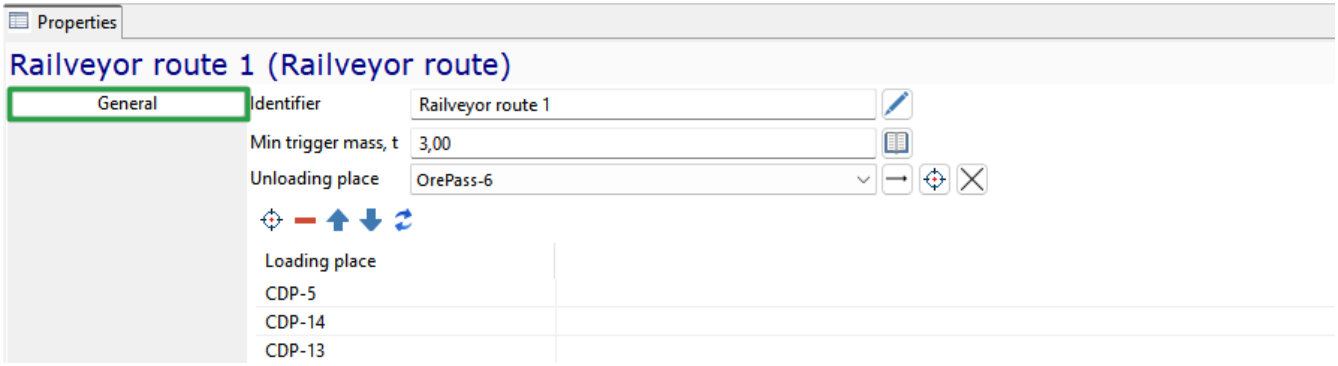
The processing plant is characterized by the following **General** parameters:

- Unique **identifier**
- **X**-, **Y**- and **Z**-coordinates
- **Performance** of ore mass processing in tons per hour
- **In flow connector** - reference to the equipment unit from which the ore mass enters the processing plant: crusher, storage or conveyor
- **Outflow connector** - reference to the equipment unit to which the ore mass enters from the processing plant: storage or conveyor.

You can set periods of **Unavailability** for the processing plant. The **Stoppages** tab provides information about all planned and probabilistic downtime periods, with a button that allows you to navigate to the corresponding editing window in the Schedules group. The **Visualization** tab is designed to create text labels for an object.

1.8.8. Railveyor route

The Railveyor route route defines a sequence of ore passes along the railway conveyor's path. The routes are fixed and contain a sequence of ore passes that the railway conveyor will unload.



The route of the railway conveyors is characterized by the following parameters:

- Unique **Identifier**
- *Minimum trigger mass in the ore pass for the start of its removal by the railway conveyor
- **Unloading place** – a link to the storage facility where the rock mass will be unloaded from the railway conveyor following this route
- **Loading place** – a list of ore passes from which the railway conveyor will load ore in the specified order during its movement along the route. Ore passes are added to the route by selecting them on the mine field using the button , and removed using the button . The order of the ore passes in the route can be changed using the arrows, and the route can be updated using the button .

1.9. Parameters of mobile equipment

Mobile equipment in MineTwin Underground is grouped by type. Equipment type is an entity used to group equipment units with the same basic characteristics.

The **Equipment types** object tree element contains lists of all equipment types that can be used for scheduling/simulation:

- Truck types
- Loader types
- Charger types
- Drilling machine types
- Roofbolter types
- Shotcrete machine types
- Shuttle car types
- Continuous miner types
- Scaler types

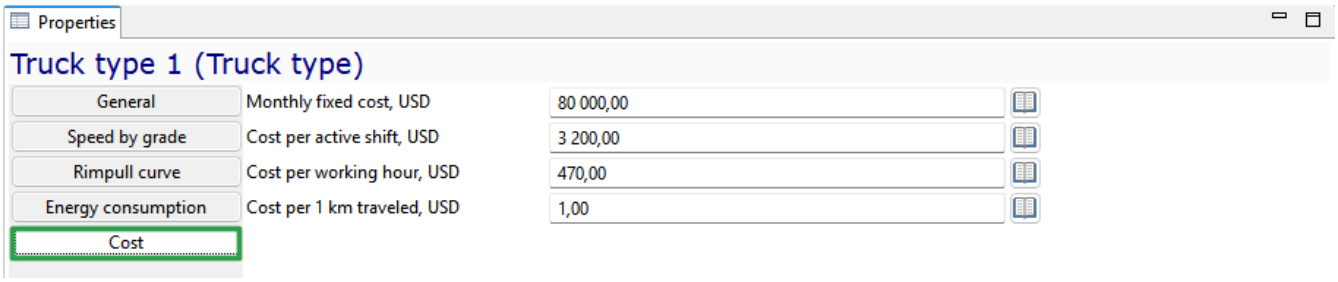
Scheduled repairs (maintenance sets), Scheduled and unscheduled (emergency) repairs sets (unplanned events) are specified in the context of equipment types.

For equipment types, the parameter **Bypassing enable** in passing manoeuvres is specified, which determines whether equipment of this type takes part in passing manoeuvres when travelling along roads for which such manoeuvres are required (mine arcs of the *Road* type with the **Opposite moving allowed**, and **Moving overtaking allowed** and **Stopped overtaking allowed** functions enabled. When traveling on the same arc, equipment passes according to the following rules:

- If two units are moving in opposite directions, the second one waits at a mine node until the first completes its travel along the arc
- If two units are moving in the same direction, they cannot overtake each other on the arc; overtaking is only possible at a node
- If a piece of equipment has stopped on a road section, the second piece will require additional time to go around it. If a piece of equipment has stopped on an edge with the Overtaking stopped equipment function disabled, then the equipment participating in passing manoeuvres will stop before this edge and wait until the road is clear.

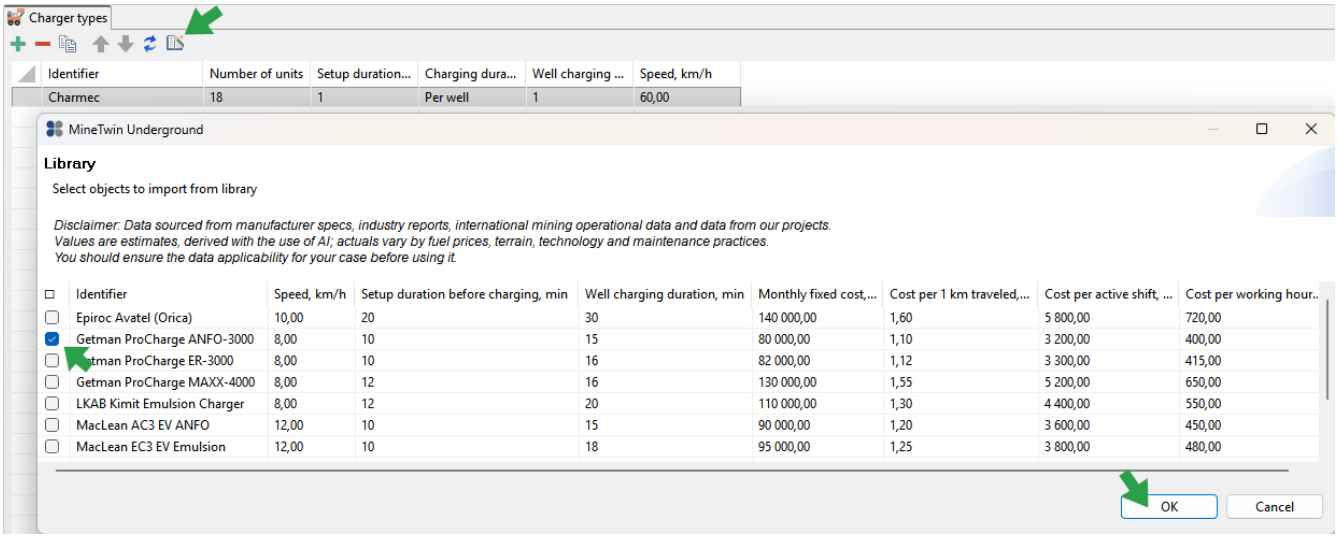
Additionally, maintenance costs for equipment types are specified at the equipment type level. On the **Cost** tab, the following cost parameters can be filled in for all equipment types:

- **Monthly fixed cost, USD**
- **Cost per active shift, USD**
- **Cost per working hour, USD**
- **Cost per 1 kilometer traveled, USD**.



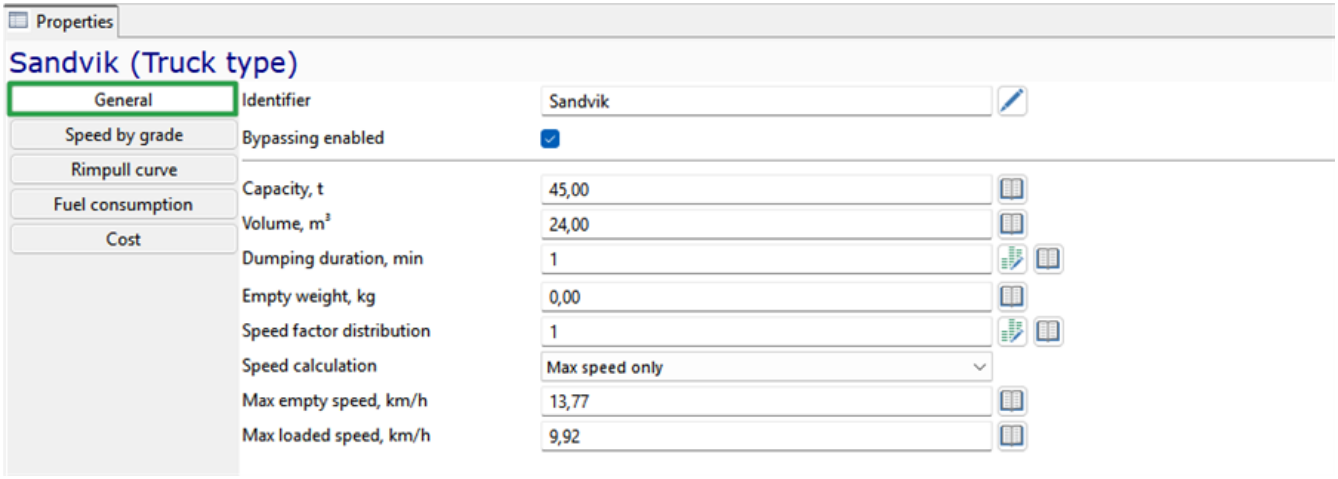
Filling in these parameters is optional and is used when estimating operational expenditures during the simulation.

MineTwin Underground contains the built-in library for commonly used equipment types. You can create an equipment type by going to the equipment library and selecting the required types of equipment and then tune it to match your equipment type.



1.9.1. Truck types

Truck - a machine designed for loading and transporting ore mass.



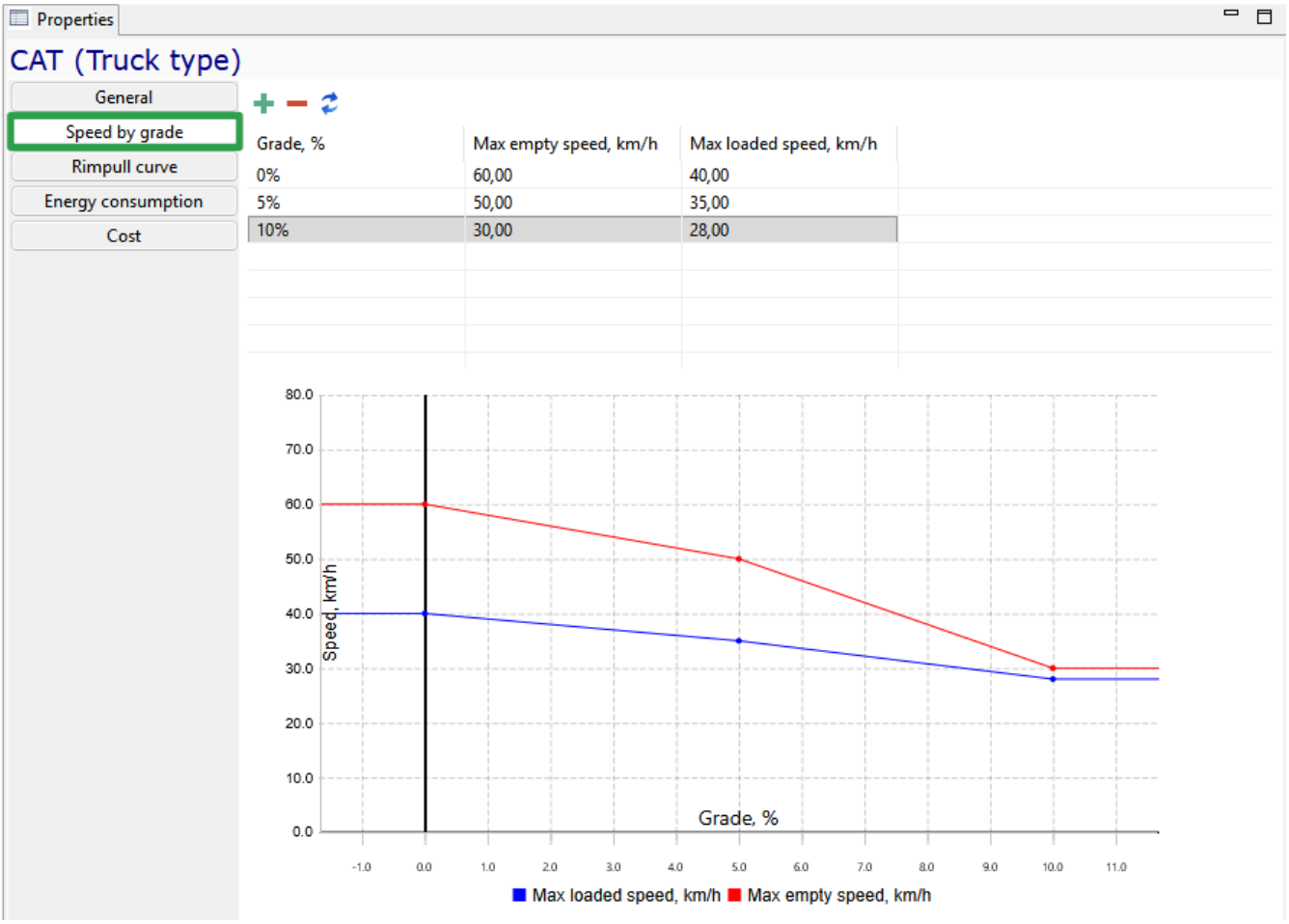
The following properties have to be set for each truck type on the **General** tab:

- Unique **identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Capacity, t** - capacity of trucks of this type in metric tons
- **Volume, m^3** - the maximum quantity of ore that the truck of this type can haul in m^3
- **Dumping duration, min**
- **Empty weight, kg** - empty truck weight in kilograms. This parameter is used in rimpull calculations
- **Speed factor distribution** - this parameter allows you to introduce variability of speed in the defined range. Parameter can be a constant or a random variable with one of the built-in distributions. The calculated speed of the vehicle will be multiplied by this parameter, and in the case of random variable the speed will be variable.
- **Speed calculation** - one of three options for calculating the speed of rock mass haulage equipment:

    - Using only the maximum speed of this equipment type. In this case, travel speed will depend solely on road quality
    - Speed calculation accounting for road gradient. In this case, simulation uses linear interpolation of a tabular speed function defined on the **Speed by grade** tab. If the defined maximum speeds are lower than those in the table, the maximum speeds will be used. The speed calculated based on gradient is also adjusted by the road quality coefficient
    - Speed calculation accounting for rolling resistance, which occurs when wheeled equipment tires roll on the road surface. In this case, a function of vehicle speed versus the force it exerts on the road is used. This function is defined on the **Rimpull curve** tab. The speed obtained by any of these rules is adjusted for road quality. On all arcs with a road quality of 1, the speed will equal the calculated value. On arcs where road quality is not 1, the speed will be adjusted by the specified coefficient. The speed factor distribution is also applied to the calculated speed.
- **Max empty speed, km/h** - absolute maximum speed of moving empty. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving empty can never be greater than this value
- **Max loaded speed, km/h** - absolute maximum speed of moving loaded. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving loaded can never be greater than this value

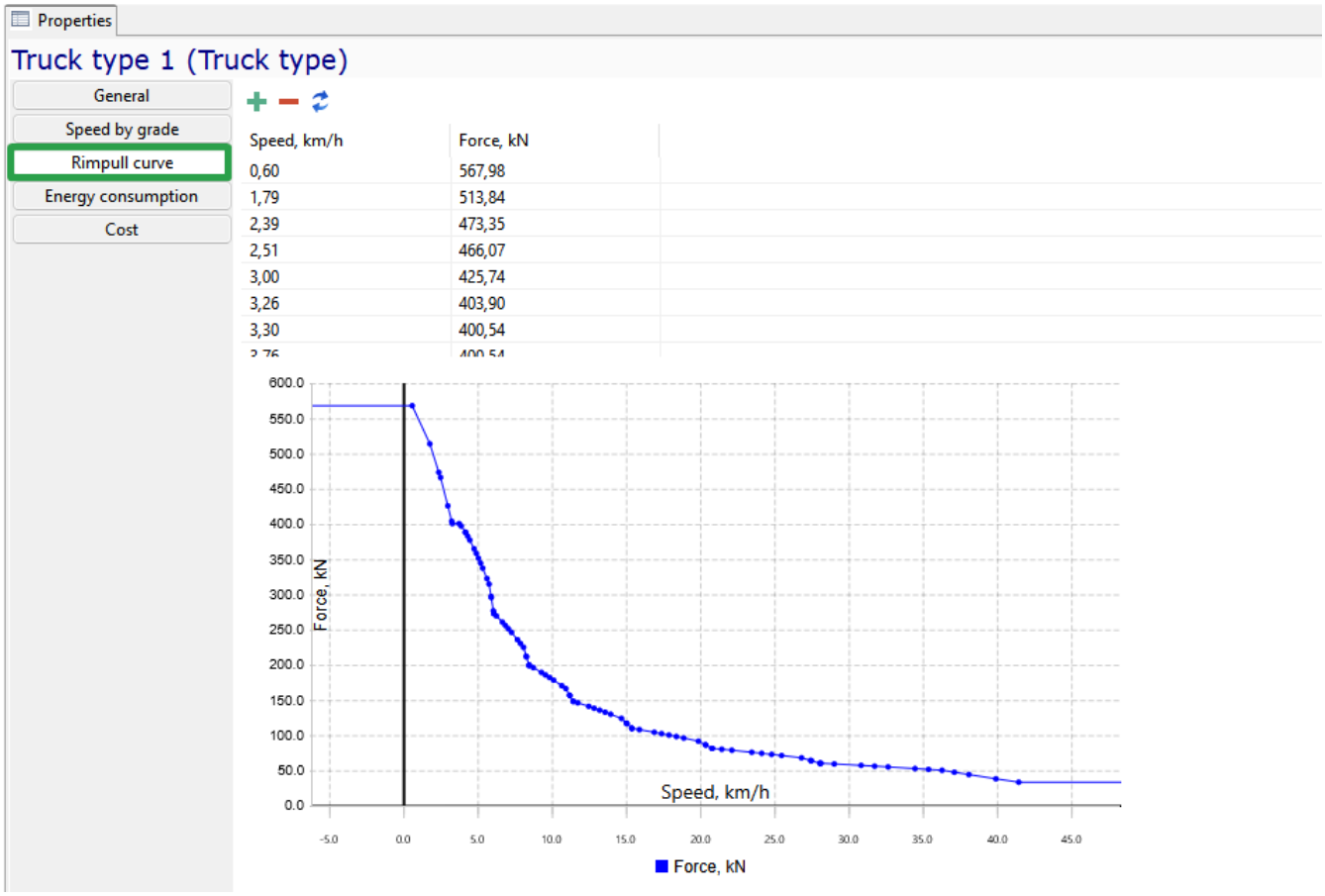
Speed by grade

On the **Speed by grade** tab, the speed characteristics of haul truck types are defined as a function of road gradient angle. For each range of angles, the corresponding travel speeds with and without load are indicated. Intermediate values are determined by linear interpolation and are displayed on the graph.



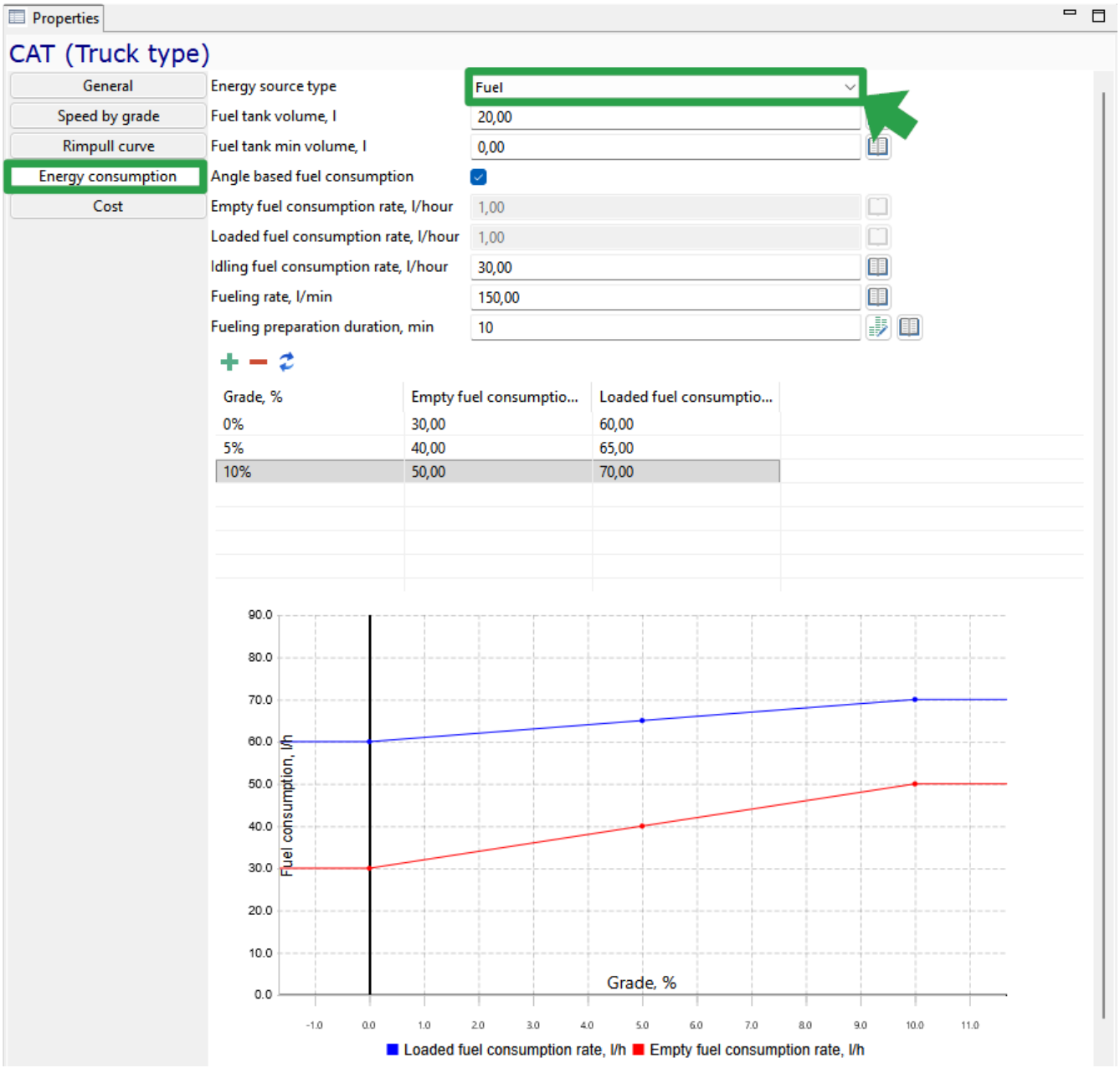
Rimpull curve

On the **Rimpull curve** tab, values describing the relationship between tractive effort (the tractive force available at the wheels) and the travel speed of a haul truck of this type can be specified. Intermediate values are determined by linear interpolation and are displayed on the graph.



Energy consumption

On the **Energy Consumption** tab, one of three available energy source options must be selected: *Fuel*, *Fixed battery*, or *Swappable battery*. After selecting the energy source, the corresponding energy consumption parameters must be filled in.



When *Fuel* is selected as the energy source, the following values are specified:

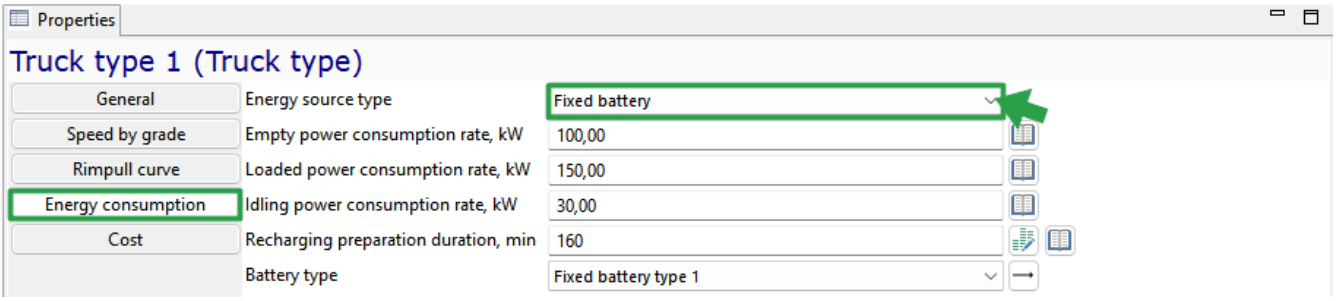
- **Fuel tank capacity, liters**
- **Fuel tank volum, liters**
- **Fuel tank min volum, liters** — the minimum volume of fuel in the tank that cannot be utilised
- **Angle based fuel consumption** — if this checkbox is selected, fuel consumption for haul trucks of this type is calculated based on fuel consumption curves vs. road gradient; otherwise, a constant consumption rate is used for various states (loaded, empty, idling). The dependencies are entered in tabular form for travel with load and without load. Road gradient is specified as a percentage, and the curves on the chart are generated automatically
- **Empty fuel consumption rate, l/hour** — constant consumption rate when travelling without load, used if the effect of road gradient does not need to be taken into account
- **Loaded fuel consumption rate, l/hour** — constant consumption rate when travelling with load, used if the effect of road gradient does not need to be taken into account
- **Idling fuel consumption rate, l/hour** — constant consumption rate when the haul truck is not

in motion

- **Fueling rate, l/min** — the refuelling rate for haul trucks of this type
- **Fueling preparation time, min** — the delay required to prepare haul trucks of this type before refuelling begins. This may be specified as either a constant or a random variable.

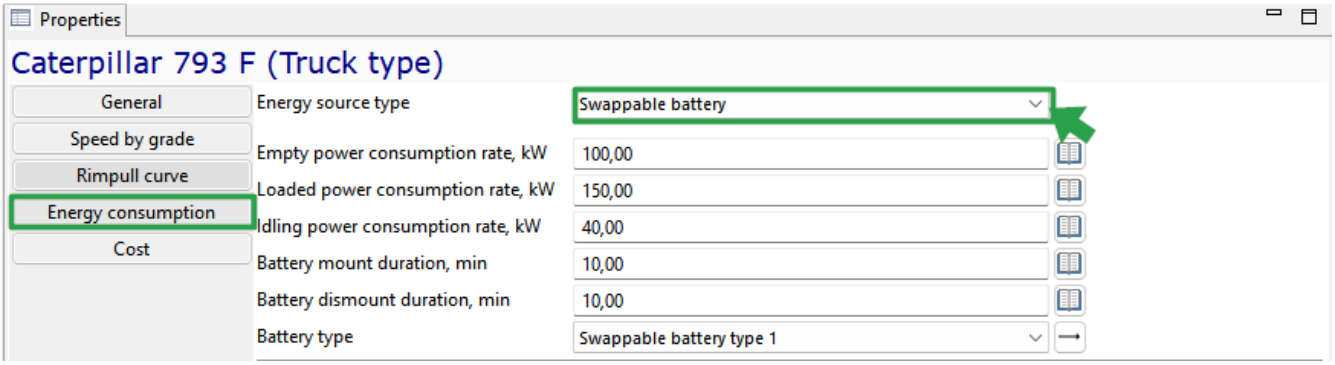
When Fixed battery is selected as the energy source, the following values are specified:

- **Empty power consumption rate, kW**
- **Loaded power consumption rate, kW**
- **Idling power consumption rate, kW**
- **Recharding preparation duration, min** — the delay before charging begins. This may be specified as either a constant or a random variable
- **Battery type** — selection of a battery type from the list available in the scenario.



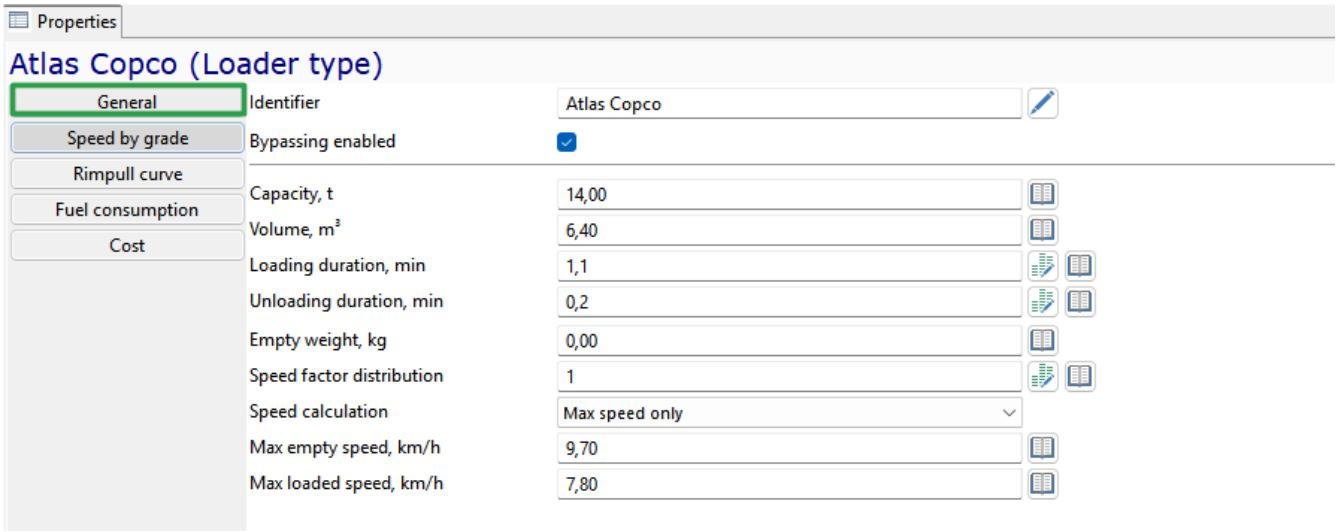
When Swappaable battery is selected as the energy source, the following values are specified:

- **Empty power consumption rate, kW**
- **Loaded power consumption rate, kW**
- **Idling power consumption rate, kW**
- **Battery mount duration, min** — the delay before charging begins. This may be specified as either a constant or a random variable
- **Battery dismount duration** — selection of a battery type from the list available in the scenario.



1.9.2. Loader types

Loader - a machine designed for loading and transporting ore mass to the dump area.



The following properties have to be set for each loader type on the **General** tab:

- Unique **identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing.
- **Capacity, t** - carrying bucket of loaders of this type in tons
- **Volume, m^3** - the maximum quantity of ore that can be placed in the load-carrying bucket of loaders of this type in m^3
- **Loading duration, min**
- **Unloading duration, min**
- **Empty weight, kg** - empty loader weight in kilograms. This parameter is used in rimpull calculations
- **Speed factor distribution** - this parameter allows you to introduce variability of speed in the defined range. Parameter can be a constant or a random variable with one of the built-in distributions. The calculated speed of the vehicle will be multiplied by this parameter, and in the case of random variable the speed will be variable.
- **Speed calculation** - one of three options for calculating the speed of rock mass haulage equipment:
  - Using only the maximum speed of this equipment type. In this case, travel speed will depend solely on road quality
  - Speed calculation accounting for road gradient. In this case, simulation uses linear interpolation of a tabular speed function defined on the **Speed by grade** tab. If the defined maximum speeds are lower than those in the table, the maximum speeds will be used. The speed calculated based on gradient is also adjusted by the road quality coefficient
  - Speed calculation accounting for rolling resistance, which occurs when wheeled equipment tires roll on the road surface. In this case, a function of vehicle speed versus the force it exerts on the road is used. This function is defined on the **Rimpull curve** tab. The speed obtained by any of these rules is adjusted for road quality. On all arcs with a road quality of 1, the speed will equal the calculated value. On arcs where road quality is not 1, the speed will be adjusted by the specified coefficient. The speed factor distribution is also applied to

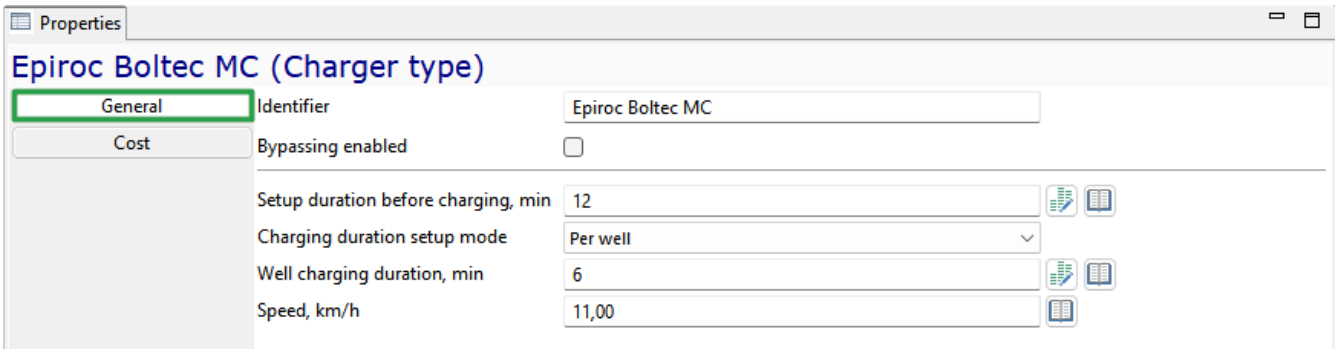
the calculated speed.

- **Max empty speed, km/h** - absolute maximum speed of moving empty. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving empty can never be greater than this value
- **Max loaded speed, km/h** - absolute maximum speed of moving loaded. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving loaded can never be greater than this value

Similarly to truck types, on the Speed by grade tab, the speed characteristics of LHD equipment types are defined as a function of road gradient angle. On the Rimpull curve tab, values describing the relationship between tractive effort and the travel speed of an LHD of this type can be specified. On the Energy consumption tab, the energy source type and its consumption parameters are specified. As with haul trucks, one of the following options is available: *Fuel*, *Fixed battery or _Swappable battery*. On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.3. Charger types

Charger - a device for the mechanized feeding of explosive material (EM) to charging planes (wells, blast holes).



The following basic properties must be set for each charger type:

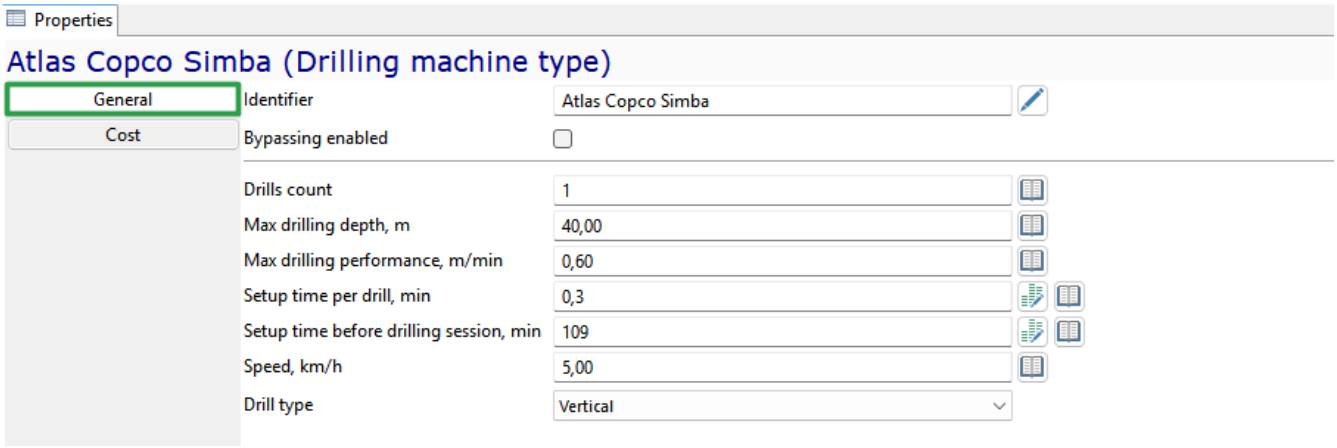
- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Setup duration before charging, min**
- **Charging duration setup mode** - one of two possible methods for accounting for the time to charge blast holes/wells with explosive material: *Time per blast hole/well* or *Time per meter of hole/well depth*
- **Well chargigng duration, min**
- **Speed, km/h** - constant travel speed of this type of chargers

The setup and charging duration can be set by a constant value or by one of the distributions.

On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.4. Drilling machine types

Drilling machine - a piece of equipment designed for drilling wells/ holes, capable of independently moving around an open-pit mine.



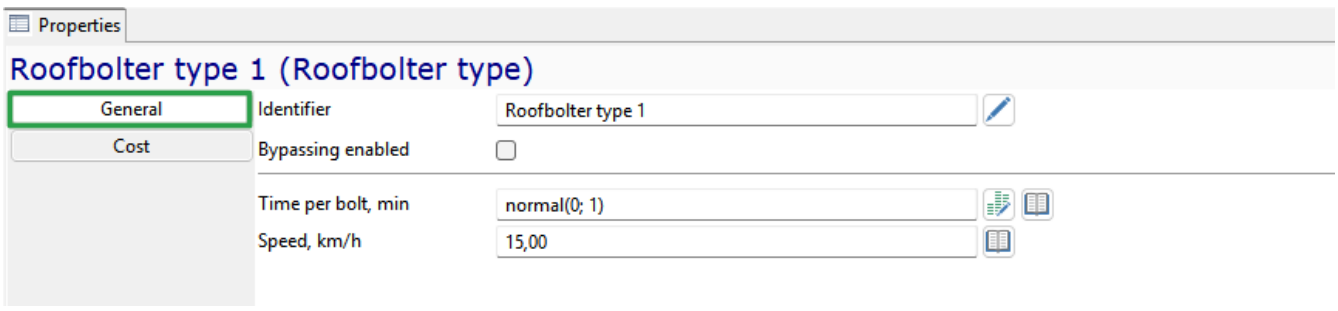
On **General** tab you can set the following properties for each drilling machine type:

- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Drills count** - the number of drilling tools. As a rule, a horizontal drilling machine has 2 booms, a vertical drilling machine has 1 boom
- **Max drilling depth, m** possible for this type of drilling machine
- **Max drilling performance, m/min**
- **Setup time per drill, min** - duration of preparatory work, such as installing the drilling machine, connecting electricity and water, etc.
- **Setup time before drilling session, min** - duration of manipulations before drilling each well/hole
- Constant **speed** of this type of drilling machines in km/h.

On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.5. Roofbolter types

Roof bolter - equipment designed for installation of roof bolting during mining operations.



On **General** tab you can set the following properties for each roofbolter type:

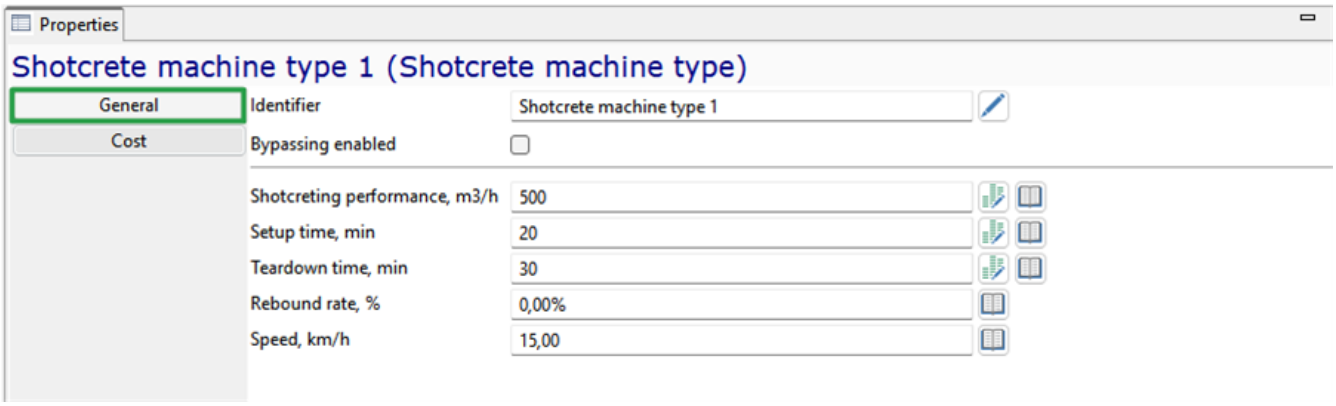
- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Time per bolt, min**
- **Speed, km/h** - average moving speed of this type of roofbolters in km/h.

The time per bolt can be set as a constant or as a random variable with one of the supported distributions.

On the tab **Cost** you can fill the cost of operating this type of equipment (but not necessarily).

1.9.6. Shotcrete machine types

A shotcrete machine is a self-propelled equipment for applying special construction mixtures to surfaces under the pressure of compressed air or water. Shotcreting of mine surfaces can be performed for additional reinforcement, waterproofing, or fire protection purposes.



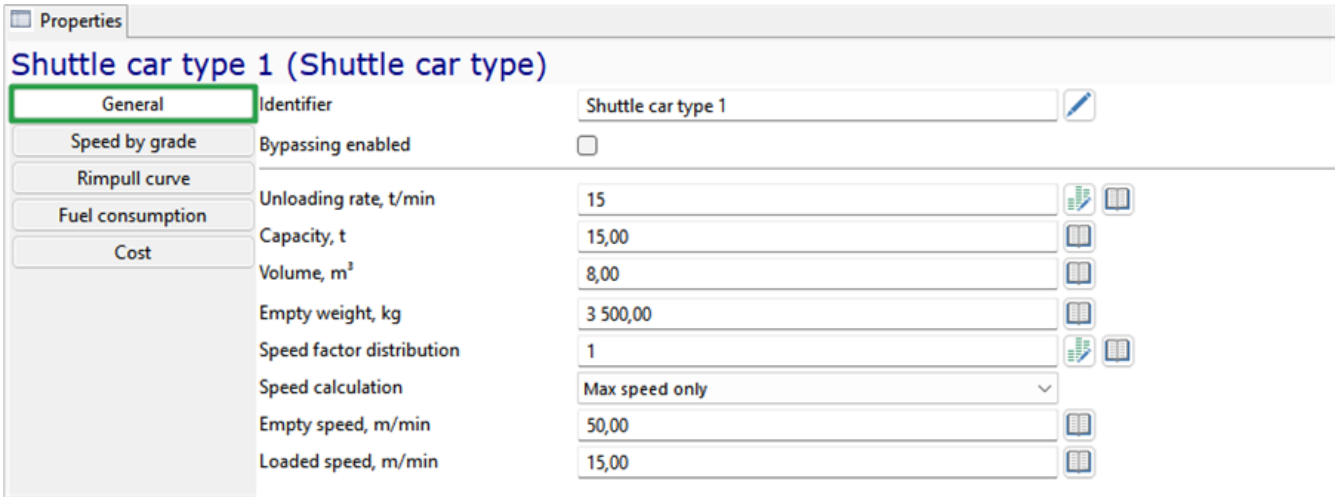
The following general properties are set for each type of shotcrete machine:

- Unique **Identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing
- **Shotcreting perfomance, m^3/h** - hourly consumption of shotcrete concrete mixture when applied to the surface
- **Setup time, min** - total time for surface preparation, dusting, etc. before the spraying process begins
- **Teardown time, min** - total time for equipment washing, rebound cleaning, quality control and other operations after the shotcreting process ends before the shotcret machine begins to move
- **Rebound rate, %** - percentage of the shotcrete mixture that does not adhere to the surface being treated during application
- **Speed, km/h** - speed of movement of the shotcrete machine

On the tab **Cost** you can fill the cost of operating this type of equipment (but not necessarily).

1.9.7. Shuttle car types

Shuttle car - equipment containing a bottom conveyor and designed for transporting ore mass in underground mines when working with continuous miners. The continuous miners load the ore mass into shuttle cars, which transfer it to the mine conveyors.



The following properties must be set for each shuttle car type:

- Unique **identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing.
- **Unloading rate** — performance of ore mass unloading in tons per minute
- **Capacity** of shuttle cars of this type in tons
- **Volume, m^3** - the maximum quantity of ore that can be placed in shuttle cars of this type in m^3
- **Empty weight, kg** - empty shuttle car weight in *kilograms*. This parameter is used in rimpull calculations
- **Speed factor distribution** - this parameter allows you to introduce variability of speed in the defined range. Parameter can be a constant or a random variable with one of the built-in distributions. The calculated speed of the vehicle will be multiplied by this parameter, and in the case of random variable the speed will be variable.
- **Speed calculation** - one of three options for calculating the speed of rock mass haulage equipment:
  - Using only the maximum speed of this equipment type. In this case, travel speed will depend solely on road quality
  - Speed calculation accounting for road gradient. In this case, simulation uses linear interpolation of a tabular speed function defined on the **Speed by grade** tab. If the defined maximum speeds are lower than those in the table, the maximum speeds will be used. The speed calculated based on gradient is also adjusted by the road quality coefficient
  - Speed calculation accounting for rolling resistance, which occurs when wheeled equipment tires roll on the road surface. In this case, a function of vehicle speed versus the force it exerts on the road is used. This function is defined on the **Rimpull curve** tab. The speed obtained by any of these rules is adjusted for road quality. On all arcs with a road quality of

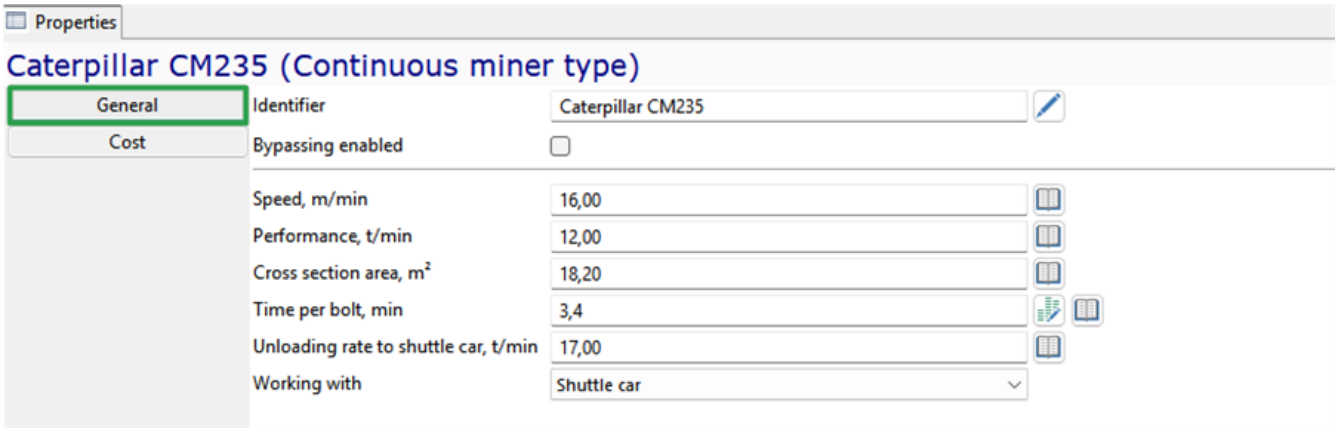
1, the speed will equal the calculated value. On arcs where road quality is not 1, the speed will be adjusted by the specified coefficient. The speed factor distribution is also applied to the calculated speed.

- **Max empty speed, km/h** - absolute maximum speed of moving empty. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving empty can never be greater than this value
- **Max loaded speed, km/h** - absolute maximum speed of moving loaded. Note that the actual speed may depend on rimpull curve data, angle-based speed settings and road quality. But the resulting speed of moving loaded can never be greater than this value

On the Speed by grade tab, the speed characteristics of LHD equipment types are defined as a function of road gradient angle. On the Rimpull curve tab, values describing the relationship between tractive effort and the travel speed of an LHD of this type can be specified. On the Energy consumption tab, the energy source type and its consumption parameters are specified. As with haul trucks, one of the following options is available: *Fuel*, *Fixed battery or _Swappable battery*. On the Cost tab, the costs for maintenance and servicing of equipment of this type are entered.

1.9.8. Continuous miner types

Continuous miner – mining equipment for mechanical breaking and destruction of the rock mass and its removal from the face. The continuous miner cuts the rock mass and transfers it to a conveyor or a shuttle car. While working, continuous miners can also install roof bolting.



The following properties must be set for each continuous miner type:

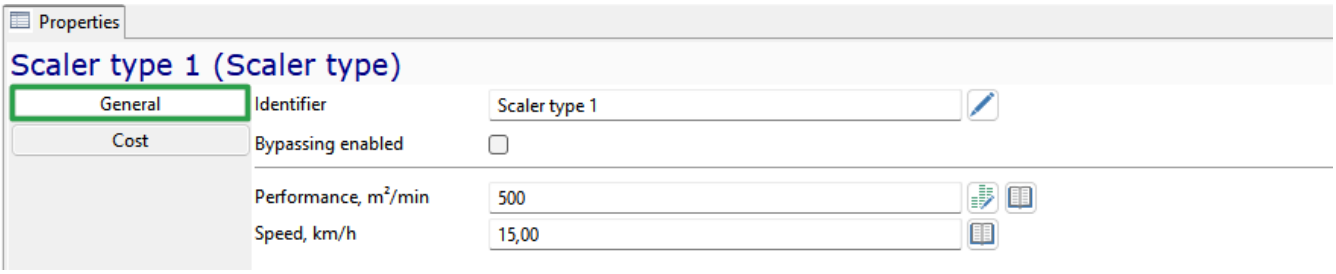
- Unique **identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing.
- **Speed, m/min** - average moving speed of this type of roofbolters in m/min.
- **Performance** of ore mass cutting in tons per minute
- **Cross section area, m^2**
- **Time per bolt, min** duration of one bolt installation in minutes
- **Working with** — is used to set whether continuous miners of this type work with *shuttle cars* or with *conveyors*.

- **Unloading rate to shattle car, t/min** - rock mass unloading rate from the continuous miner into the shuttle car. This field is filled in when working with shuttle cars

On the tab **Cost** you can fill the cost of operating this type of equipment (but not necessarily).

1.9.9. Scaler type

A **Scaler** is a self-propelled unit used to remove loose rock and irregularities from the surface of a stope.



For each type of **Scaler**, the following key properties must be specified:

- Unique **identifier**
- **Bypassing enabled** - if checked, the equipment unit of this type will participate in bypassing maneuvers when traveling along the arcs that require vehicle bypassing.
- Scaling **performance**, m^2 per minute
- **Speed, km/h** - average moving speed of this type of roofbolters in km/h.

On the tab **Cost** you can fill the cost of operating this type of equipment (but not necessarily).

1.9.10. Mobile equipment

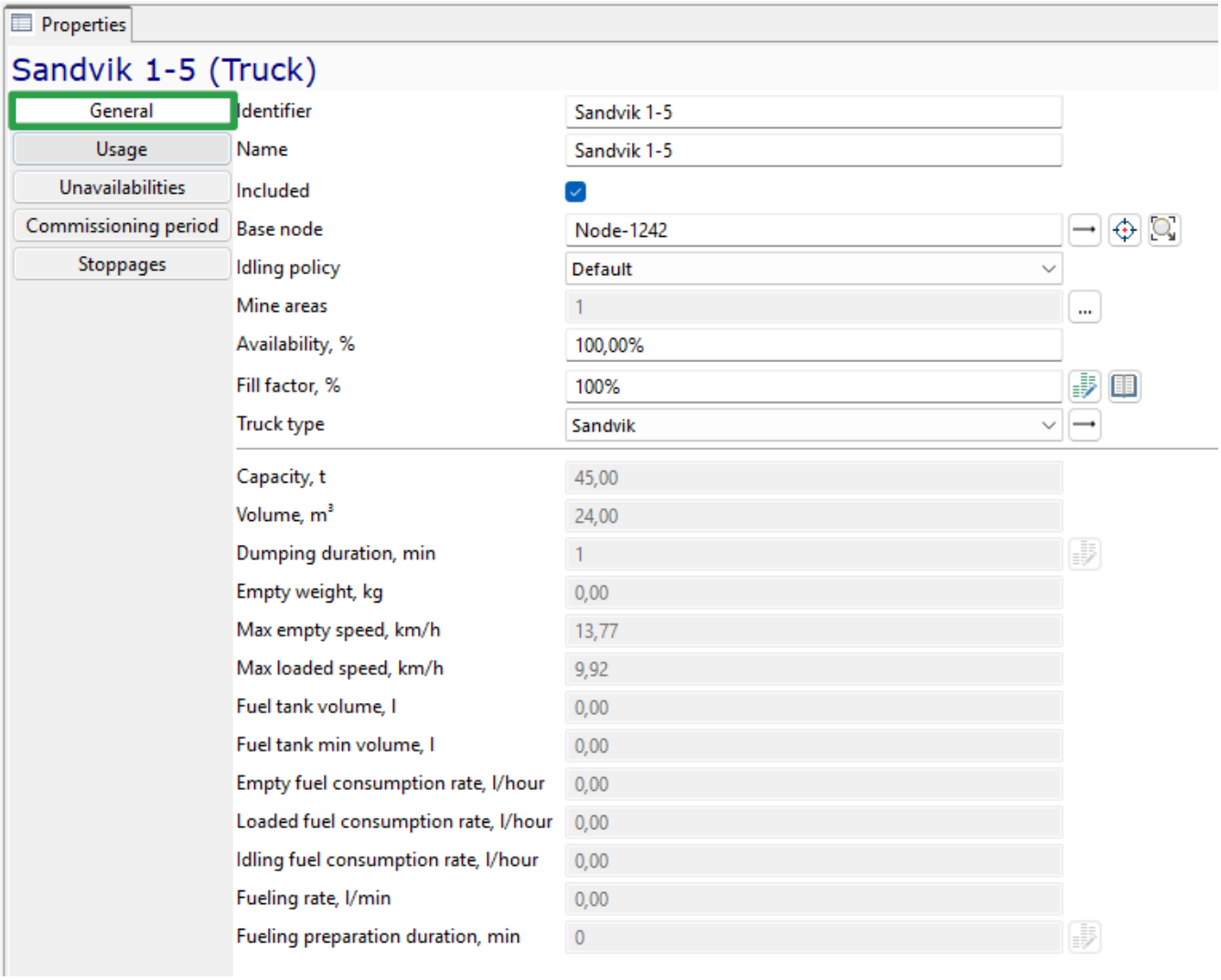
The **Mobile Equipment** element of the object tree contains lists of all mobile equipment units defined in the scenario, organized by equipment type. It also includes a list of underground trains and railveyors, which — unlike other mobile equipment — are not grouped into types.

General parameters

Each equipment unit, except for trains and rail conveyors, is defined by the following key properties:

- Unique **identifier** of the equipment unit
- **Included** — indicates whether the equipment unit will be used during planning/simulation
- **Base node** — the default location of the unit on the mine map (garage)
- **Idling policy** — action after completing tasks:
  - *Default* — trucks and LHDs return to the garage; drill rigs and bolters remain in the stope
  - *Return to base node* — all equipment returns to the garage after completing work
  - *Stay at current location* — all equipment remains at the location where it finished its last task

- **Mine area** or **Mine areas** to which the equipment unit is assigned
- **Availability, %** — the average percentage of time the equipment is in operation. During planning/simulation, breaks are automatically generated so that the average availability of the equipment over the simulation period — before applying other downtime periods — matches the specified value
- **Equipment type** — displayed as reference information in the equipment properties; its properties cannot be edited



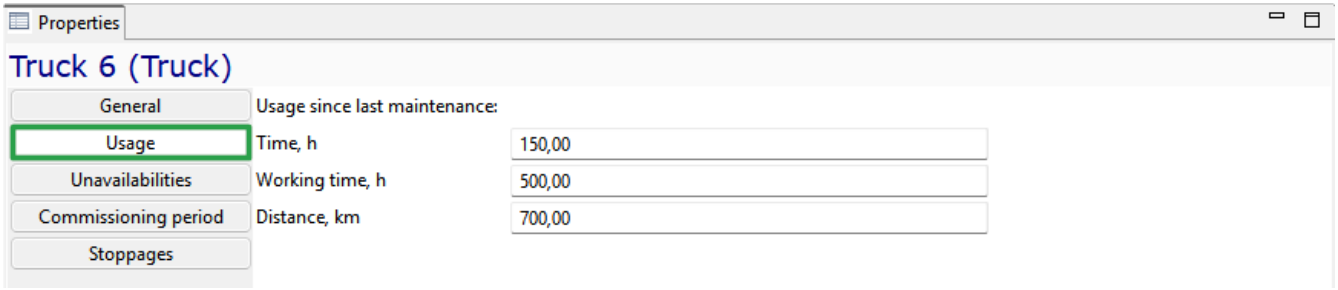
In addition to these main properties, there are equipment-specific properties applicable only to certain equipment types:

- For trucks, LHDs, and shuttle cars — **Fill factor**, which allows modeling variability of equipment load (constant or stochastic)
- For shuttle cars — **Maximum haulage distance, in meters**
- For continuous miners — **Buffer capacity in tonnes and Volum in m³**

Usage

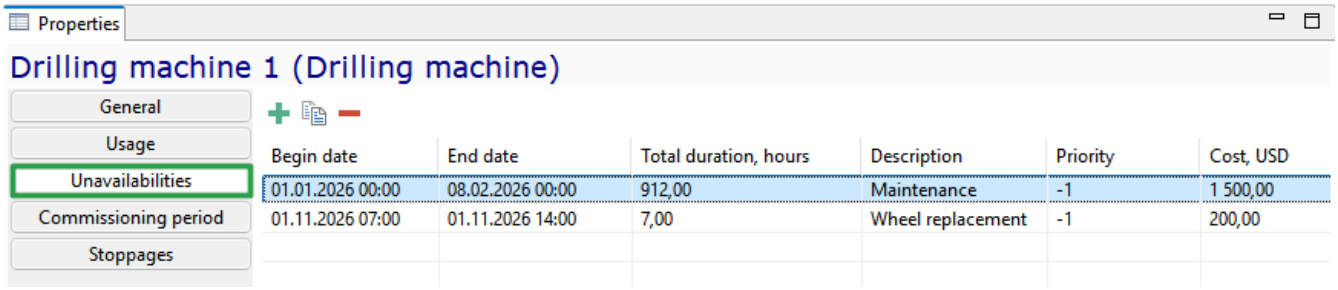
On the **Usage** tab, the initial state of parameters related to maintenance based on operating hours is specified for each mobile equipment unit:

- **Time, h** — total time accumulated by the equipment unit since its last maintenance at the start of planning/simulation
- **Working time, h** — number of engine hours (hours of engine operation during travel, loading, unloading) accumulated by the equipment unit since its last maintenance at the start of planning/simulation
- **Distance, km**— number of kilometres travelled by the equipment unit since its last maintenance at the start of planning/simulation



Unavailabilities

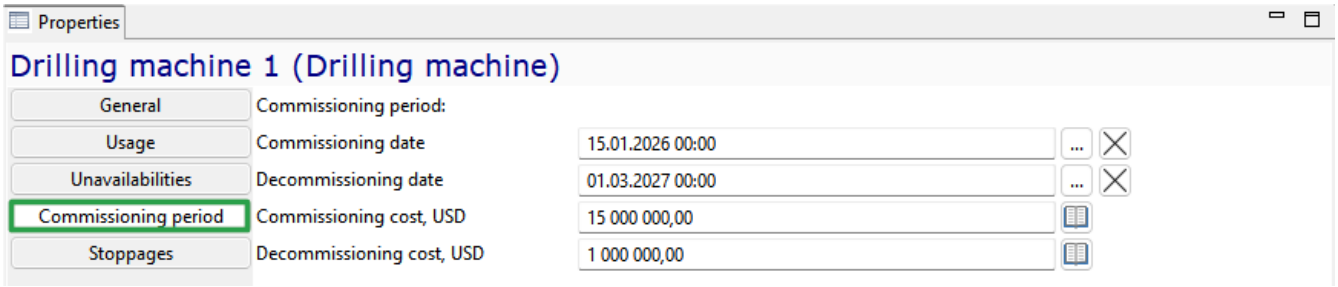
On the **Unavailabilities** tab, scheduled periods of unavailability can be specified for each equipment unit.



The  buttons allow you to add, copy, and delete unavailability periods.

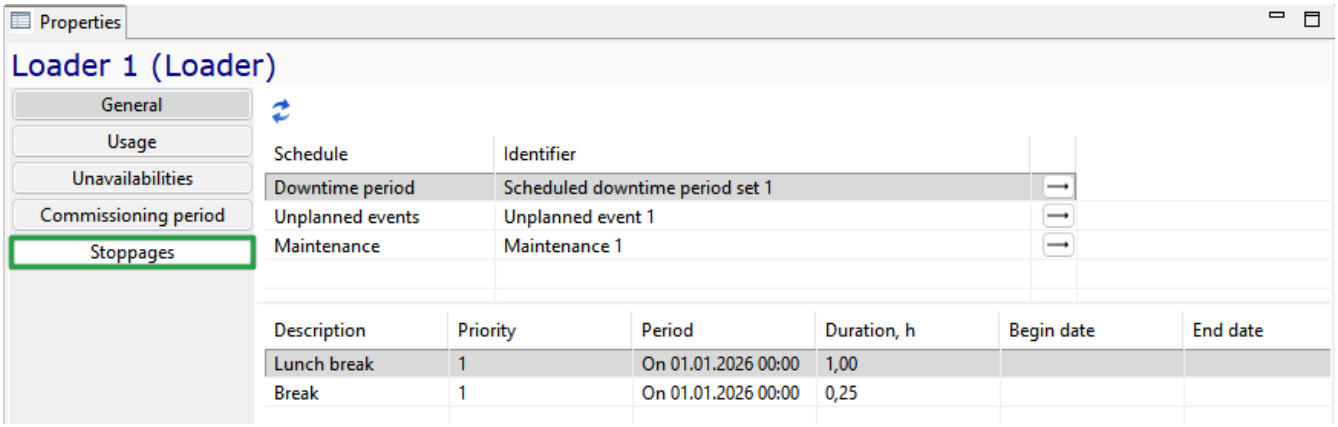
Commissioning period

On the **Commissioning period** tab, the commissioning and decommissioning dates of an equipment unit may be specified, as well as the costs associated with commissioning (purchase) and decommissioning (disposal). Prior to the commissioning date / after the decommissioning date, the equipment unit does not participate in planning/simulation.



Stoppages

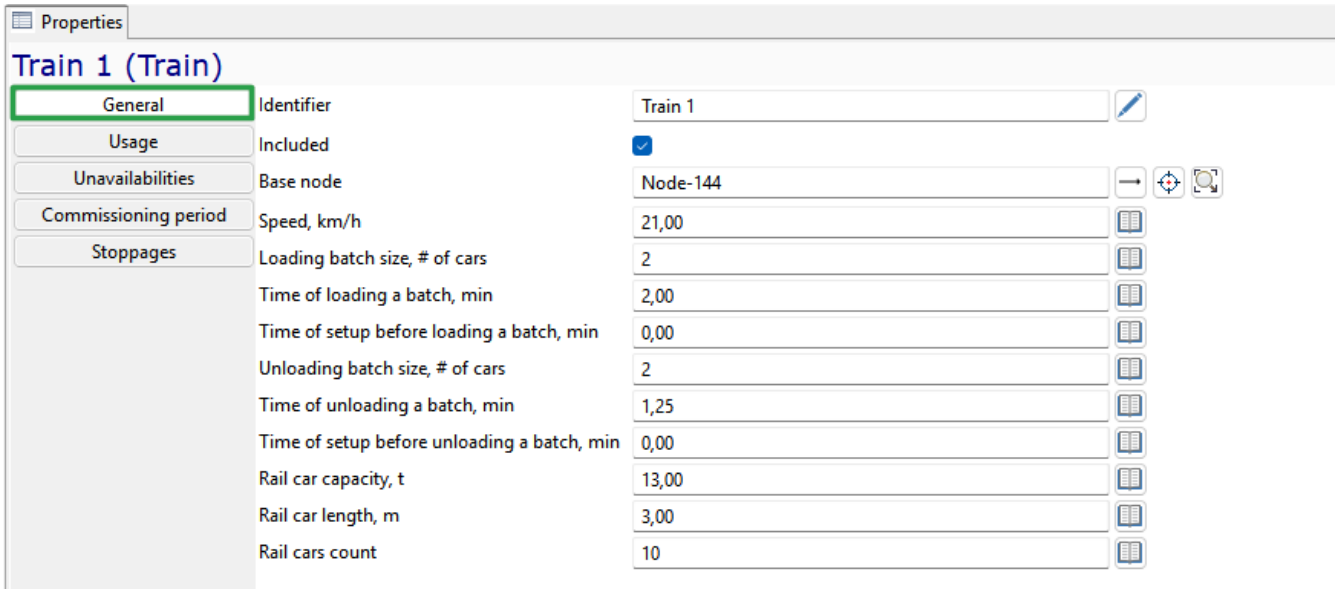
On the **Stoppages** tab, all downtime events (maintenance, scheduled downtime periods, unplanned events) assigned to the equipment unit in the **Schedules** object tree group are displayed.



The button allows you to refresh the list of schedules, and the button allows you to navigate to the selected schedule for editing.

Train

Train - a transport unit in the form of a separate train that consists of several rail cars, designed to transport ore mass on the rails. Unlike other mobile equipment, trains are not grouped into types.



The following basic parameters are set for a train:

- Unique **identifier**
- **Included** - parameter that indicates whether the equipment unit will be used for scheduling/simulation
- **Base node** - base location (depo)
- **Speed, km/h**
- **Loading batch size, number of cars** - how may rail cars can be loaded simultaneously
- **Time of loading a batch, min** - loading duration, min
- **Time of setup before loading a batch, min** - delay before loading can start
- **Unloading batch size, number of cars** - how may rail cars can be unloaded simultaneously
- **Time of unloading a batch, min** - unloading duration, min

- **Time of setup before unloading a batch, min** - delay before unloading can start
- **Rail car capacity, t** - capacity of one rail car in metric tons
- **Rail car length, m** - Length of one rail car in meters
- **Rail cars count** - number of rail cars in the train.

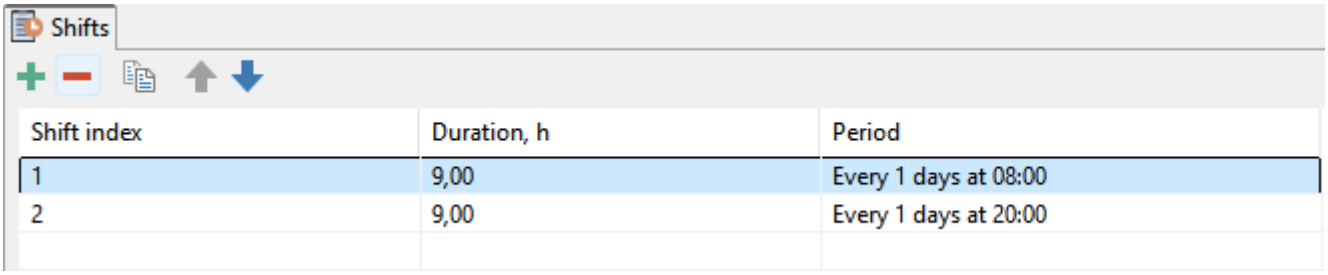
1.10. Schedules

The **Schedules** model tree element contains the following entities that regulate the work of the mine:

- Shifts
- Blast periods
- Schedule downtime period sets
- Maintenance sets
- Unplanned events.

1.10.1. Shifts

Shifts are used to simulate the operation of equipment following the work schedule. Shifts determine the periods when equipment is available for operation.



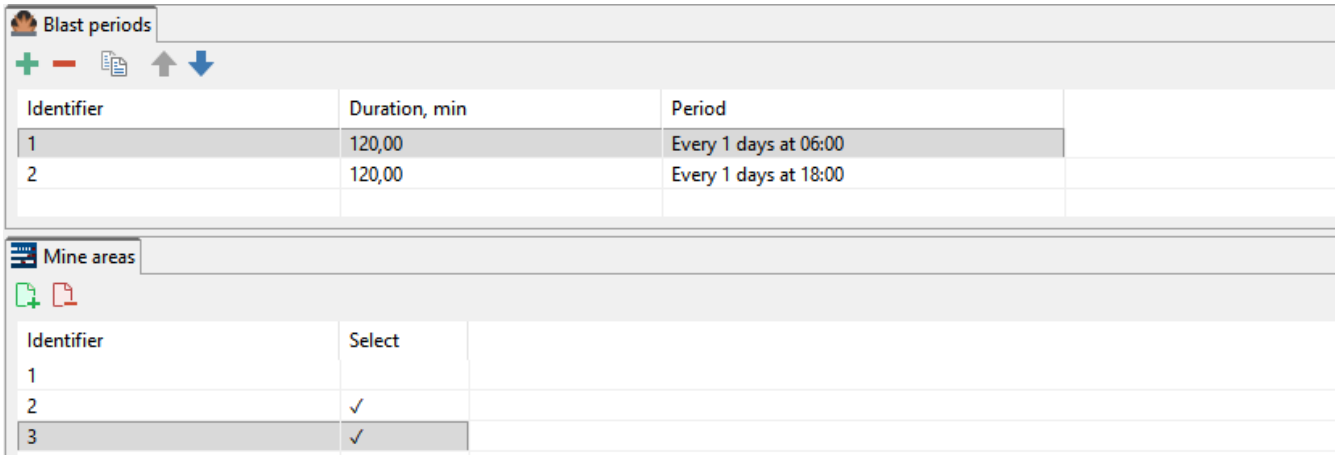
The following parameters are set for each shift:

- **Shift index** - an optional field to indicate a shift
- **Duration** of shift, in hours
- **Period** - the period of the shift can be specified as an exact time or as a recurrence pattern (every n-th day of the month, every last day of the month, every week, every n days).

Shifts in the **Shifts** model tree group are common to all mobile equipment units and applied during scheduling and simulation only to them.

1.10.2. Blast periods

Blast periods define the time intervals when the formation of broken-up ore mass is simulated in all blocks in selected mine areas that are ready for blasting at the start of the blast period.



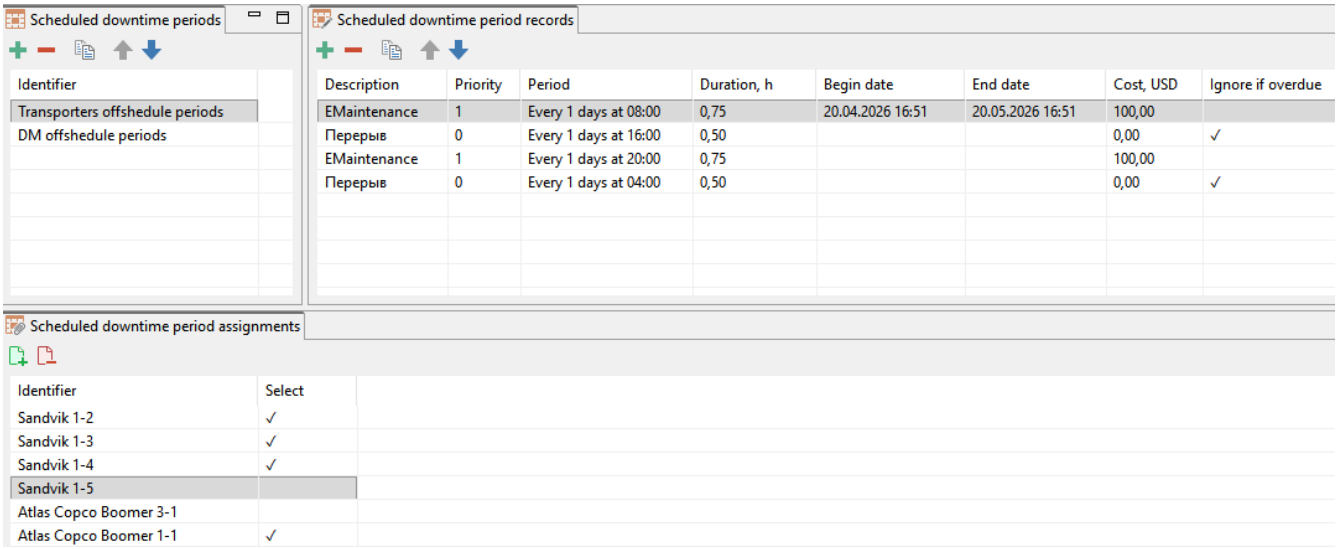
The **Blast period** has following parameters:

- Unique **identifier** of the blast period
- **Duration** of the blast period in minutes
- **Period** of the blast period, which can be specified as an exact time or as a recurrence pattern (every n-th day of the month, every last day of the month, every week, every n days)
- **Mine areas** where the above blasting operations are carried out.

The **Blast periods** model tree element contains a list of all blast periods that can be assigned to the mine areas during scheduling and simulation.

1.10.3. Scheduled downtime period sets

Scheduled downtime period sets are used to model planned periods of equipment unavailability within a fixed time interval, regardless of the equipment's operating time, engine hours, or mileage. In this way, this period sets can represent lunch breaks, routine shift maintenance (RSM), major repairs, or equipment upgrades.



Three types of entities are created in MineTwin OpenPit to set up **Scheduled downtime period sets**:

- **Scheduled downtime periods** in the upper-left window, each possibly containing several

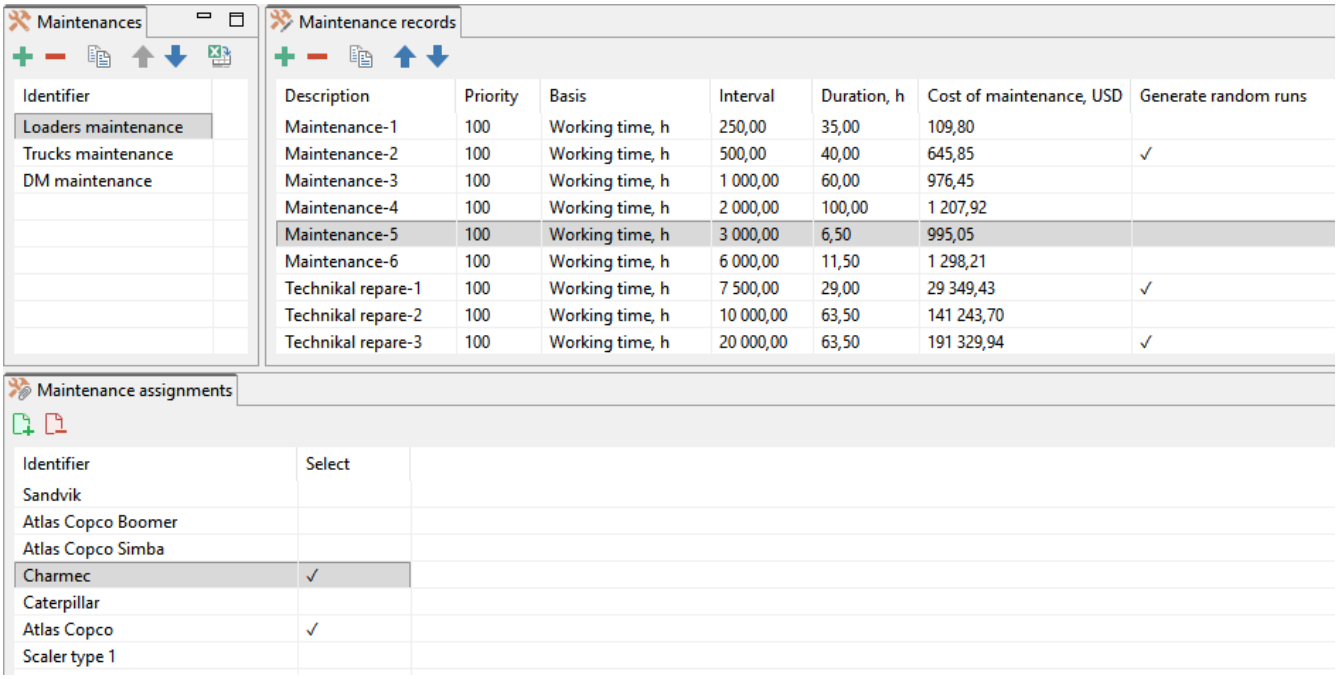
individual **Scheduled downtime period records**

- **Scheduled downtime period record** — a row of data describing a single downtime in the upper-right **Scheduled downtime period records** window. A downtime record is defined by the following parameters:
  - **Description** — an optional description of the scheduled downtime period
  - **Priority** — an index defining the position in the hierarchy of unavailability periods. Periods with a smaller value of the index (higher priority) overwrite periods with higher value (lower priority). Lower priority unavailability periods will not be scheduled if they occur during periods with higher priority.
  - **Duration, h** — the length of the planned downtime period, in hours
  - **Begin and end dates** — specified if the downtime occurs only during a limited time frame, e.g., winter months. If left blank, the downtime applies throughout the entire scenario.
  - **Cost, USD** — the expenses associated with carrying out this downtime type, e.g., routine shift maintenance (RSM) cost
  - **Ignore if overdue** — if checked, this parameter allows to ignore the downtime if its time interval has already passed. For example, a truck has a scheduled lunch break from 13:00 to 14:00, but it is still waiting to be loaded by an excavator that is on break. In this case, the truck effectively experiences a break during that wait, so there is no need to simulate an additional one-hour break once the truck completes its trip after the excavator returns.
- **Scheduled downtime period assignments** window at the bottom allows you to assign **Scheduled downtime periods** to selected equipment units.

The buttons  allows you to select all equipment units / clear all selections.

1.10.4. Maintenances

Maintenance sets are used to simulate scheduled equipment repairs — those carried out after a specified calendar time of operation, upon reaching a defined number of engine/impact mechanism hours, or upon reaching a specified mileage. In this way, different types of maintenance can be defined, such as routine maintenance, intermediate repairs, major overhauls, etc.



Three types of entities are created in MineTwin OpenPit to set up **Maintenance sets**:

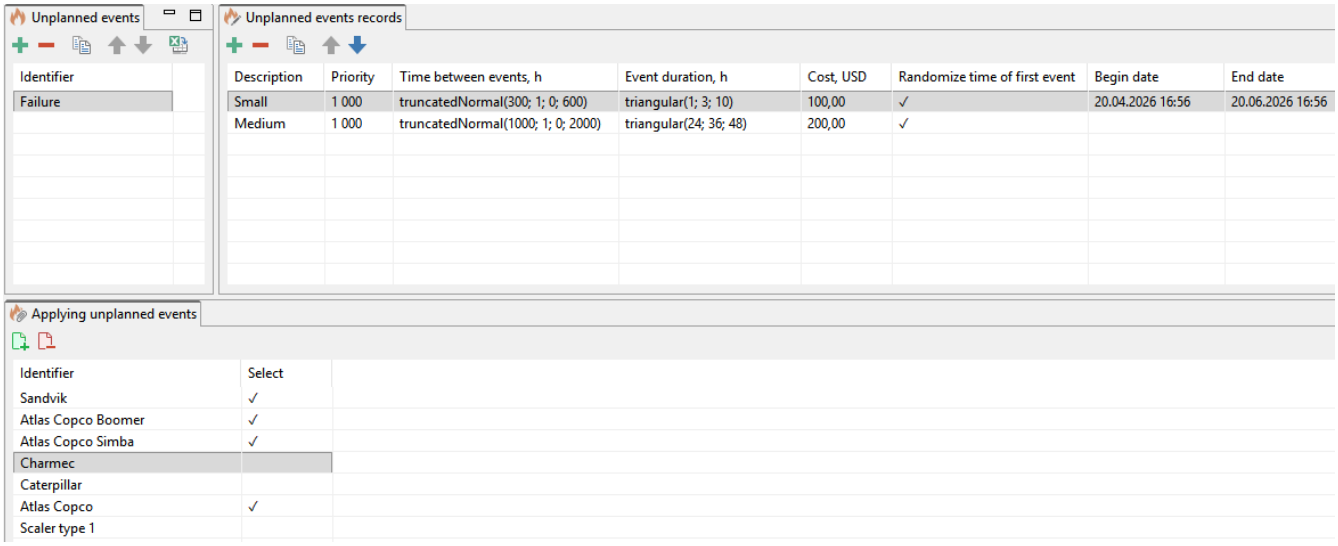
- **Maintenances** in the upper-left **Maintenances** window, each possibly containing several individual **Maintenance records**
- **Maintenance record** — a row of data describing a single maintenance/repair in the upper-right **Maintenance records** window. A maintenance is defined by the following parameters:
  - **Description** — an optional description of the maintenance/repair
  - **Priority** — an index defining the position in the hierarchy of unavailability periods. Periods with a smaller value of the index (higher priority) overwrite periods with higher value (lower priority). Lower priority unavailability periods will not be scheduled if they occur during periods with higher priority.
  - **Basis** — the type of maintenance trigger: calendar time, engine operating hours, or equipment mileage.
  - **Interval** — the interval between two maintenance triggers, expressed either in hours or kilometers, depending on the chosen basis.
  - **Duration, h** — the duration of the maintenance
  - **Cost, USD** — the expenses associated with the maintenance (optional)
  - **Generate random runs** — if checked, maintenance for all equipment units without a defined initial operating time will not be simulated simultaneously. Instead, maintenance triggers will occur at different randomly assigned times for each unit.
- **Maintenance assignments** window at the bottom allows you to assign **Maintenances** to selected equipment types.

The buttons  allows you to select all equipment types / clear all selections.

1.10.5. Unplanned events

Unplanned events are used to simulate emergency equipment failures, breakdowns, or downtime

caused by weather conditions.



To define **Unplanned events** in MineTwin OpenPit, three types of entities are created:

- **Unplanned events** in the upper-left **Unplanned events** window, each possibly containing several individual **Unplanned events records**
- **Unplanned events record** — a row of data describing a single **Unplanned event** in the upper-right **Unplanned events records** window. Such event is defined by the following parameters:
  - **Description** — an optional description of the event
  - **Priority** — an index defining the position in the hierarchy of unavailability periods. Periods with a smaller value of the index (higher priority) overwrite periods with higher value (lower priority). Lower priority unavailability periods will not be scheduled if they occur during periods with higher priority.
  - **Time between events, h** — may be specified as a constant or as a random variable using one of the built-in distributions.
  - **Event duration, h** — may be specified as a constant or as a random variable using one of the built-in distributions.
  - **Cost, USD** — the expenses associated with the event (optional)
  - **Randomize time of first event** — used so that equipment failures are not simulated simultaneously for all units; instead, the countdown starts at different randomly assigned times for each unit
  - **Begin and end dates** — specified if the events occur only during a limited time frame, e.g., winter months. If left blank, the events will happen throughout the entire scenario.
- **Unplanned events assignments** window at the bottom allows you to assign **Unplanned events** to selected equipment types.

The buttons  allows you to select all equipment types / clear all selections.

Note: **Scheduled downtime periods** are assigned to *Equipment units* and most *Material flow elements*, while **Maintenances** and **Unplanned events** are assigned to *Equipment types* and *Conveyers*.

1.10.6. Hierarchy of Unavailability Periods

For each equipment unit, different types of unavailability periods can be defined:

- Blasting periods, scheduled downtime periods, maintenance, and unplanned events (via schedules)
- Commissioning/decommissioning and unavailability (in equipment properties)

During planning/simulation, these periods may overlap in time. Priorities are used to regulate overlapping periods.

Breaks with a lower priority index are higher priority and override (absorb) breaks with a higher index (lower priority). By default:

- Unavailability periods and out-of-service periods have the highest priority = -1
- Scheduled downtime periods = 1
- Maintenance = 100
- Unplanned events = 1000

This means that if a major repair (priority -1) coincides with a daily lunch break (priority 1), the lunch break will not be scheduled. If a failure (priority 1000) occurs during current maintenance (priority 100), that failure will not be considered in the simulation.

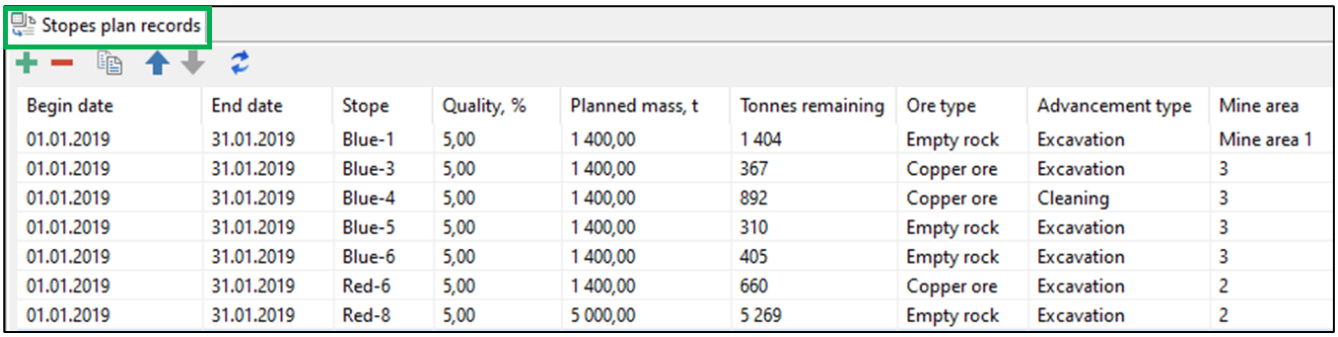
If necessary, the user can adjust the priorities of unavailability periods.

1.11. Plans

MineTwin Underground can automatically form an equipment operation plan based on target plans for mining ore mass or stopes.

1.11.1. Stopes plan

The stopes plan specifies how much ore mass and what quality must be mined in each period in each stope.



Begin date	End date	Stope	Quality, %	Planned mass, t	Tonnes remaining	Ore type	Advancement type	Mine area
01.01.2019	31.01.2019	Blue-1	5,00	1 400,00	1 404	Empty rock	Excavation	Mine area 1
01.01.2019	31.01.2019	Blue-3	5,00	1 400,00	367	Copper ore	Excavation	3
01.01.2019	31.01.2019	Blue-4	5,00	1 400,00	892	Copper ore	Cleaning	3
01.01.2019	31.01.2019	Blue-5	5,00	1 400,00	310	Empty rock	Excavation	3
01.01.2019	31.01.2019	Blue-6	5,00	1 400,00	405	Empty rock	Excavation	3
01.01.2019	31.01.2019	Red-6	5,00	1 400,00	660	Copper ore	Excavation	2
01.01.2019	31.01.2019	Red-8	5,00	5 000,00	5 269	Empty rock	Excavation	2

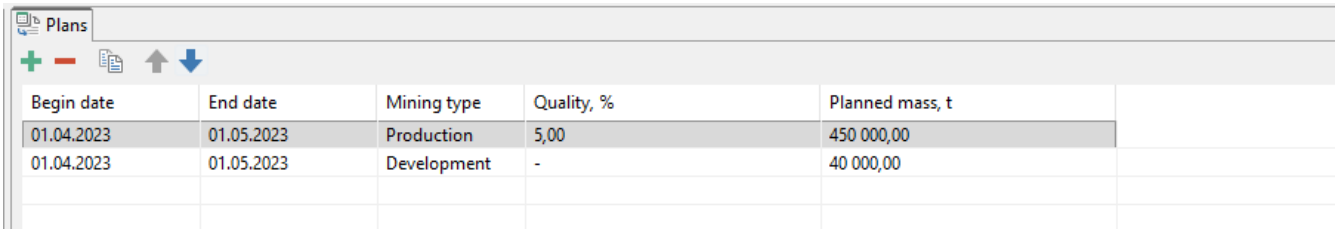
Each stopes plan record is characterized by the following parameters:

- **Begin** and **end dates** of the planning period
- **Stope**

- **Quality** of the mined ore mass
- **Planned mass, t.**
- **Remaining mass, t** – quantity of remaining ore mass in stopes
- **Ore type**
- **Advancement type**
- **Mine area**.

1.11.2. Target plan

The target plan specifies how much ore mass and what quality must be mined in each target period in total.



Begin date	End date	Mining type	Quality, %	Planned mass, t
01.04.2023	01.05.2023	Production	5,00	450 000,00
01.04.2023	01.05.2023	Development	-	40 000,00

Each target plan record is characterized by the following parameters:

- **Begin** and **end dates** of the planning period
- **Mining type**
- **Quality** of the mined ore mass
- **Planned mass, t.**

2. Scheduling and simulation

The scheduler is intended for scheduling equipment operation, taking into account:

- Target values for production volumes and ore quality
- Sequences of the mine technological cycle
- Duration of operations performed by the selected equipment
- Lengths of the hauling distances, geometric distance of the stopes
- Equipment operating schedules
- Scheduled equipment repairs and other routine maintenance
- Blasting schedules.

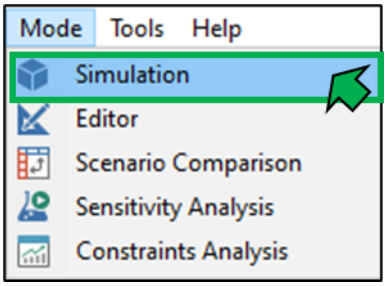
The simulation model checks the feasibility of the scheduler's plan, taking into account:

- Unscheduled repairs (failures)
- Delays due to vehicles passing in busy areas of the mine
- Loading queues
- Unloading queues in front of the ore passes due to erratic loading on them
- Decreased throughput of in-mine haulage due to uneven ore supply

In MineTwin scheduling mode, one shift scheduling and simulation is performed sequentially. At the end of the shift, the scheduler performs scheduling for the next one based on the results of the execution of the previous shift plan by the simulation model.

2.1. Simulation management

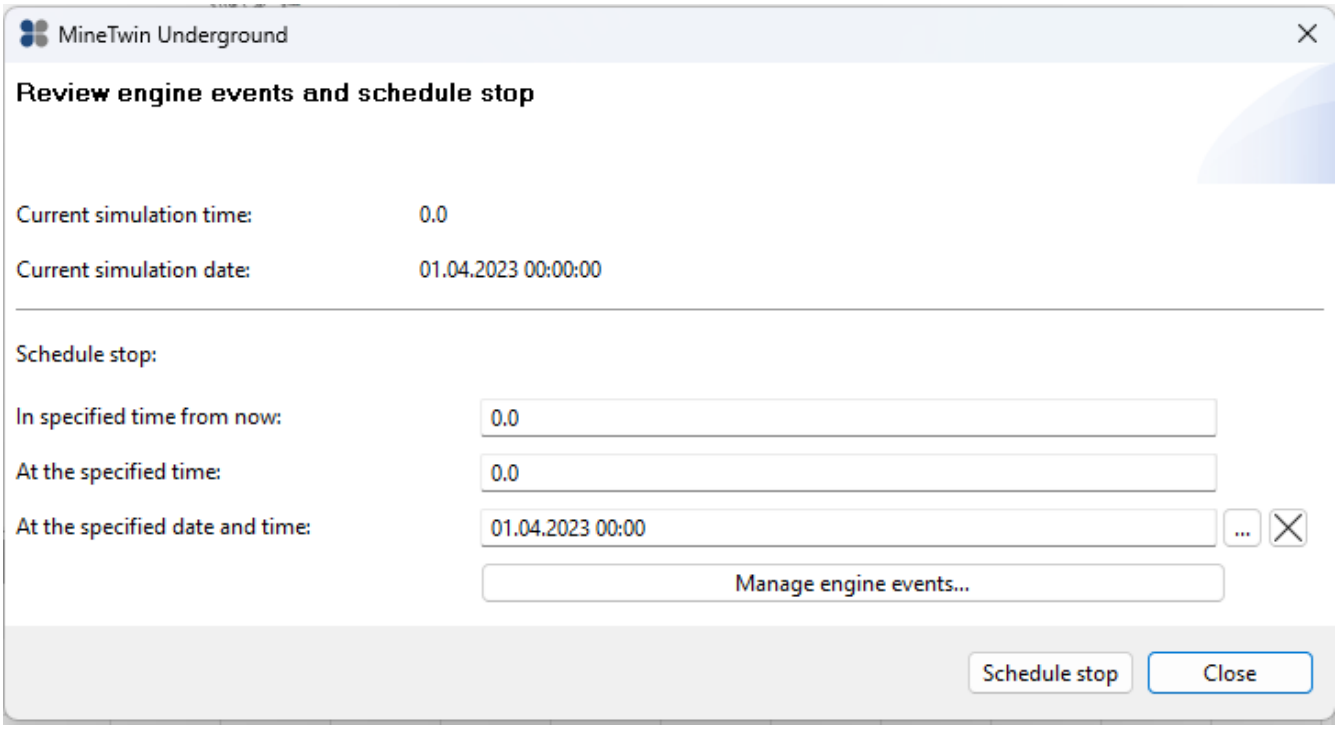
You can switch to planning/modeling mode by selecting **Simulation** in the **Mode** menu or by clicking the **Simulate** button on the toolbar.



To start the simulation, use the button on the top toolbar of the scheduling module window.

To pause the model, use the button .

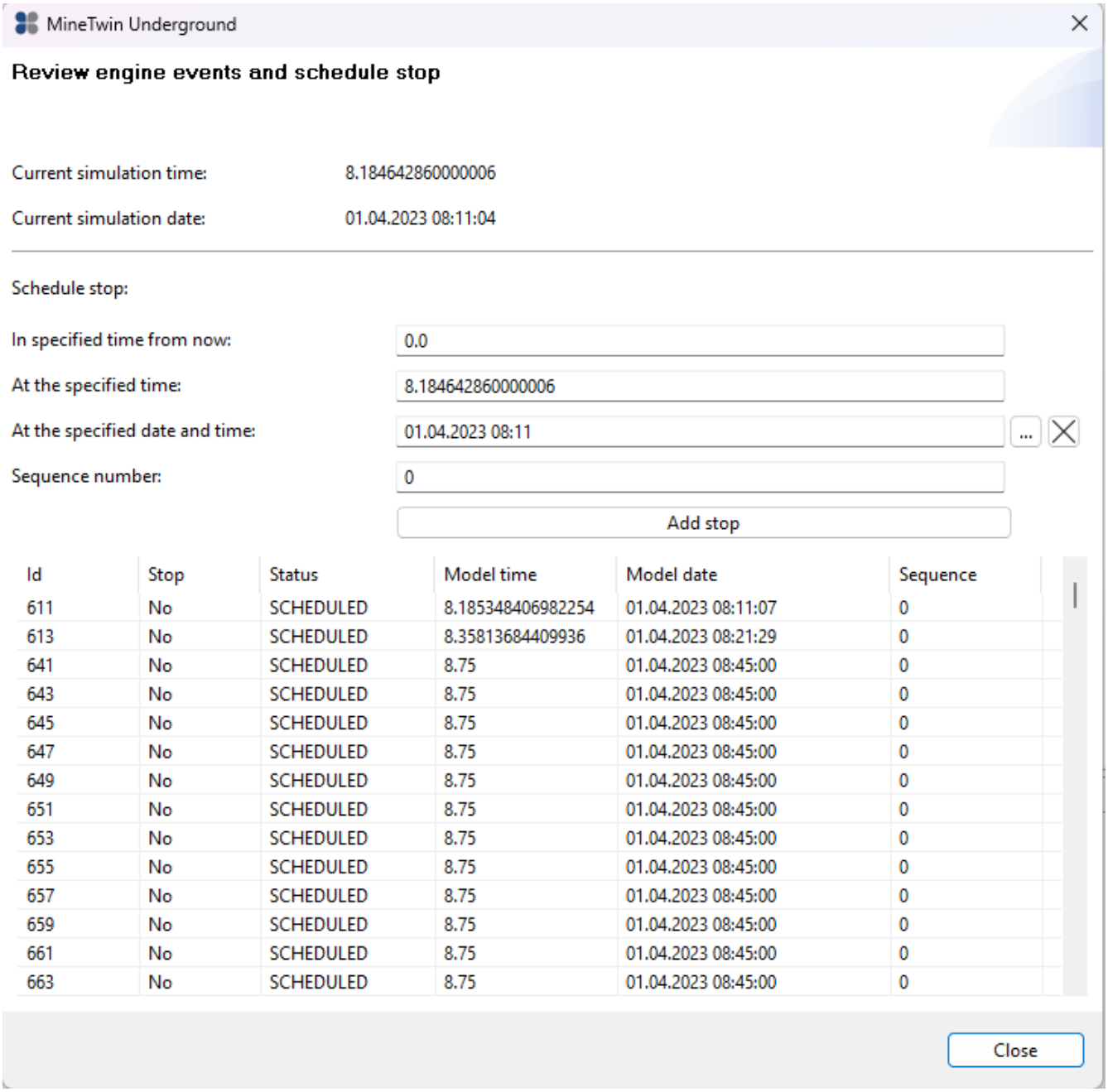
To create a stop at the desired simulation time, use the button.



When you click this button, a window appears where you can specify after how many *simulation hours*, at what *simulation time* (in hours), or at what *simulation date and time* the simulation should stop. When one of these parameters is set, the others are recalculated automatically.

When you click **Schedule Stop**, the stop is created, the window closes, and the simulation resumes.

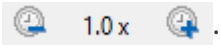
To create multiple stops, you can use the technical mode **Manage engine events...**, which is opened by clicking the corresponding button.



In this mode, stops are created by clicking **Add Stop** and are displayed in the table below, where you can see both the stops you created (value in the **Stop** column — *Yes*) and other system events (value in the **Stop** column — *No*).

The **Sequence number** field defines the order in which the system processes events that occur at the same time.

To exit the stop-creation mode, click **Close**.

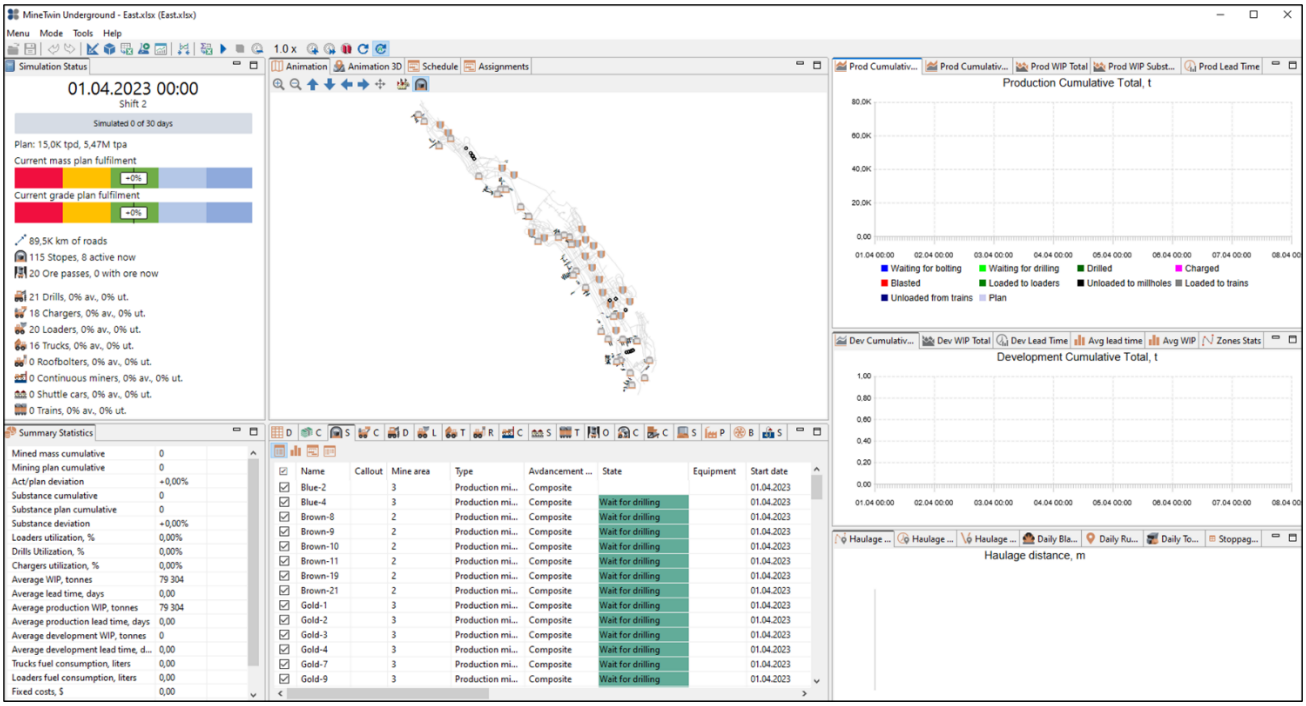
To accelerate/slow down the simulation, use the buttons 

.

For maximum acceleration, use the button  .

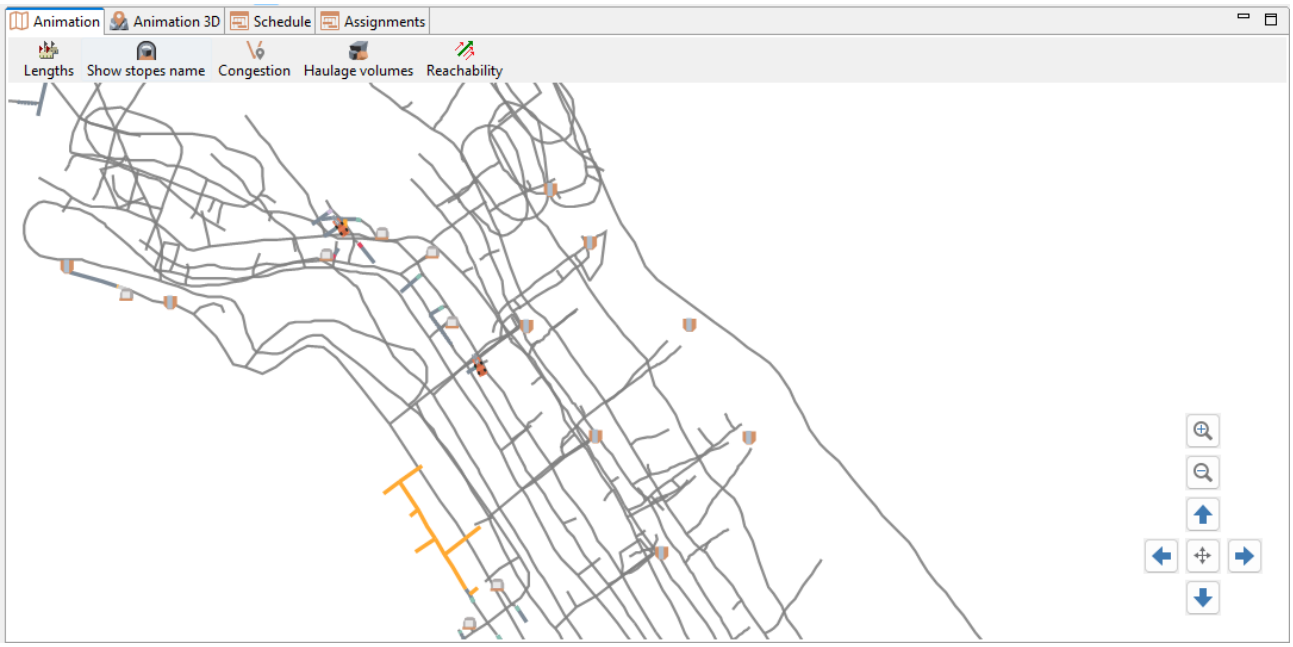
2.2. Visualization of simulation results

The layout of the simulation window is shown in the figure below.



2.2.1. Animation

2D animation dynamically displays the simulation process in 2D space: simulation of the movement and equipment/transport operation on the mine map.



In the lower-right corner of the **Animation** window, there are buttons that make working with the map easier. The buttons allow users to zoom in and out, and the buttons allow you to pan the map. The button centers the map so that the entire mine is visible at once.

The top toolbar of the animation window contains buttons that control the display of additional information.

The button shows the lengths of the minefield segments, and the button displays the names of the stopes on the map.

The button highlights road sections where vehicles move slower than their potential maximum speed due to congestion, slopes, or surface conditions. The color varies for each section:

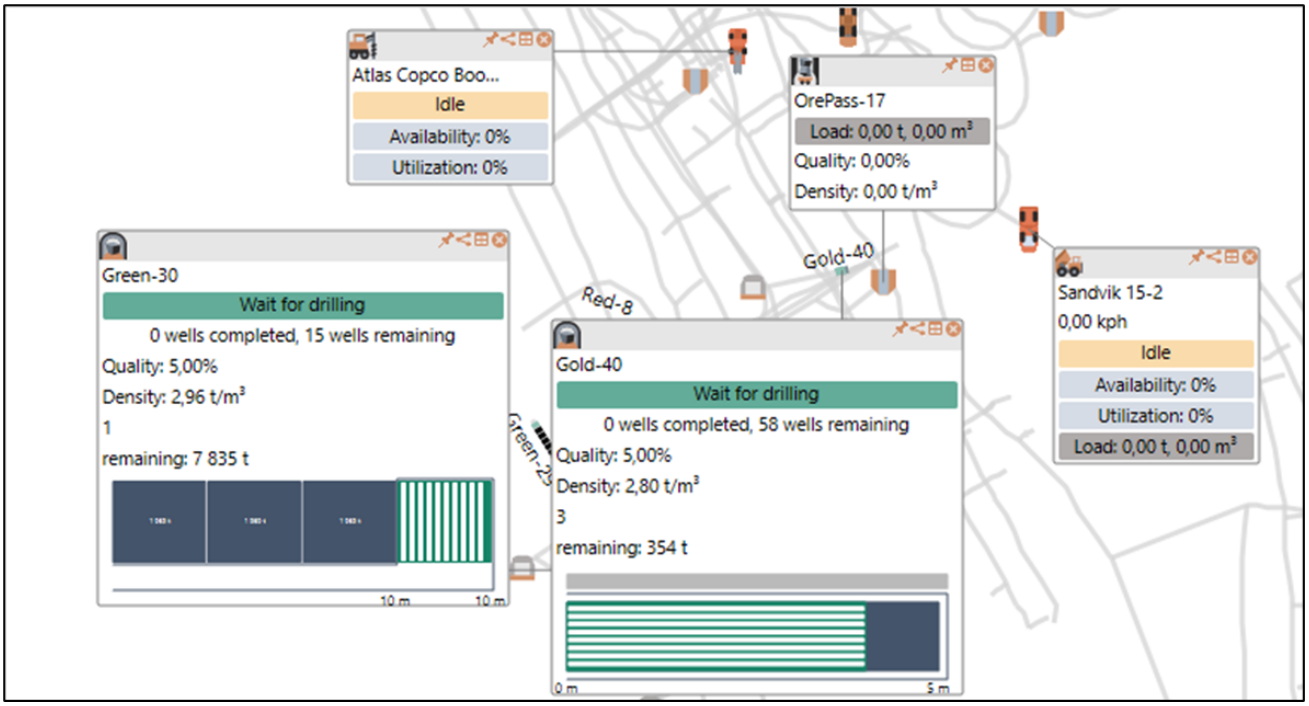
- Red — equipment is slowed down — the section is overloaded or problematic;
- Green — equipment moves freely — the section is functioning normally.
- Gray indicates that there is no data (no vehicles passed over this section during the selected period).

The button highlights route load based on the haulage volume of ore mass transported by loaders/trucks.

The button highlights connected graphs of the transport network. The disconnected segments will be shown with different color.

Clicking on the equipment unit opens a window with information about the status of the equipment unit, its availability and equipment utilization.

Clicking on a stope opens a window with information about the status of the stope, the quality and density of the ore mass in the stope.

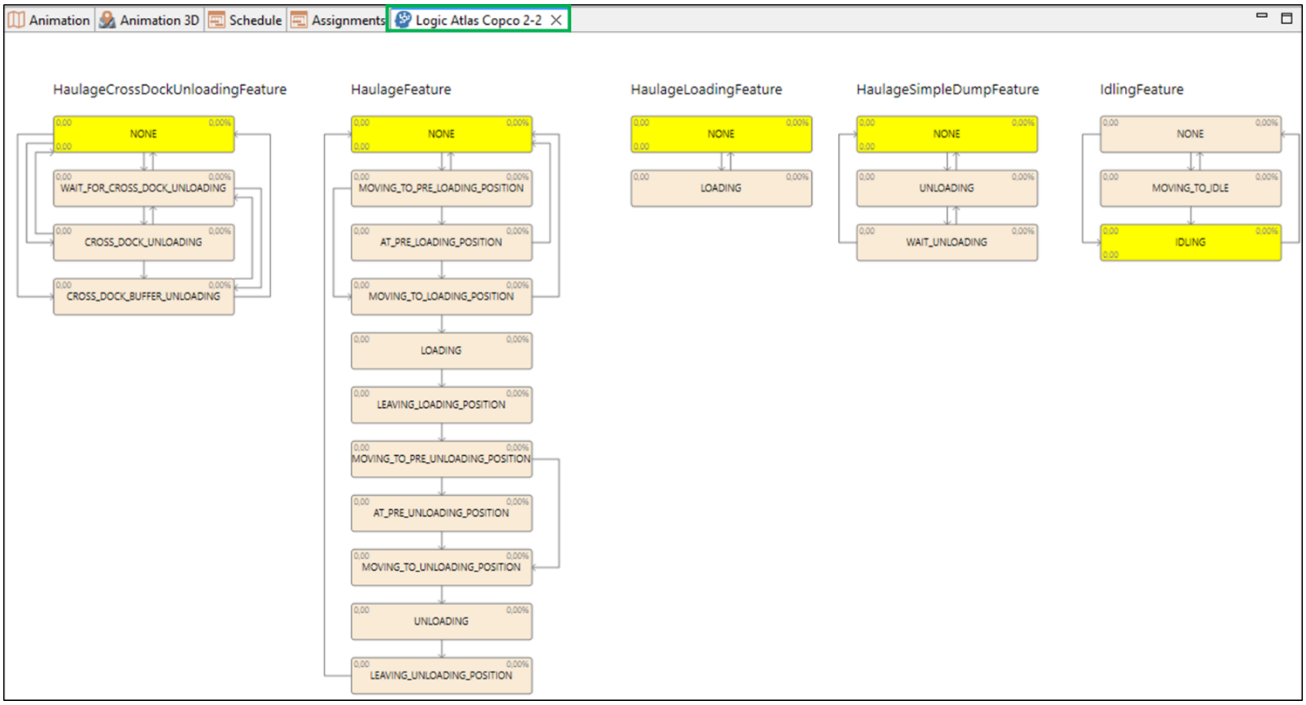


Clicking on the dump area, its loading, quality and density of the ore mass at the dump area are displayed.

The button in the information window closes the window.

The button activates the table with the list of equipment units and highlights the selected unit.

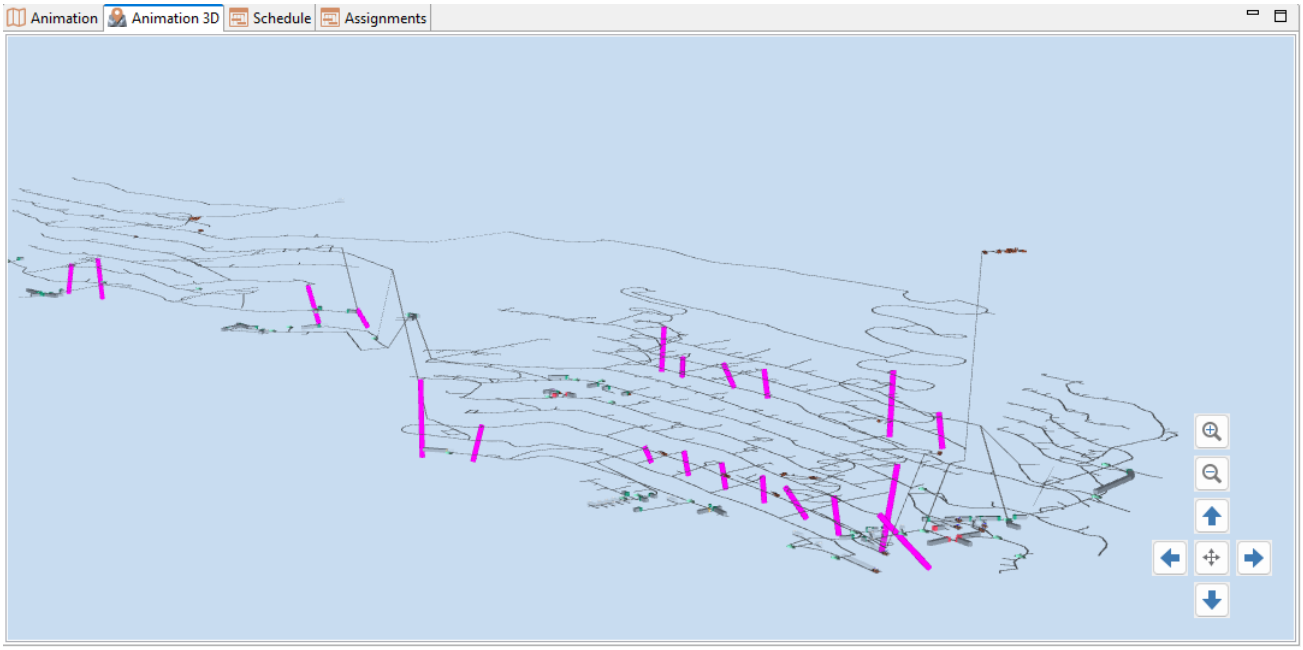
The button activates the technical state-chart table, which can be used for model debugging.



The button  pins the information window to the map, allowing it to move together with the map.

2.2.2. Animation 3D

3D animation dynamically displays the simulation process in 3D space: simulation of the movement and equipment/transport operation on the mine 3D map.



Clicking on the equipment unit opens a window with the name of the equipment unit.

In the lower-right corner of the 3D Map window, there are buttons that make working with the map easier. The  button centers the map so that the entire mine is visible at once. The  buttons allow you to zoom the map in and out, and the  buttons allow you to pan the map.

2.2.3. Schedule

In the **Schedule** window of the simulation mode, the Gantt chart displays planned states for the stopes (drilling, charging, blasting, hauling, etc.), and planned tasks for the equipment. As the simulation runs, the execution of the plan is shown dynamically: both adherence to the planned schedule and any deviations from it. image::image172.png[Gantt chart displaying equipment schedules with color-coded tasks and time allocations on 01.04.2023 and 03.04.2023.,width=656,height=306]

To start the simulation, use the button on the top toolbar of the **Schedule** window.

The simulation can be restarted to the desired simulation time. To do this, place the vertical time marker at the desired date and click the button.

You can make the elements in the **Schedule** view larger using the button (*Normal* mode) or more compact using the button (*Compact* mode).

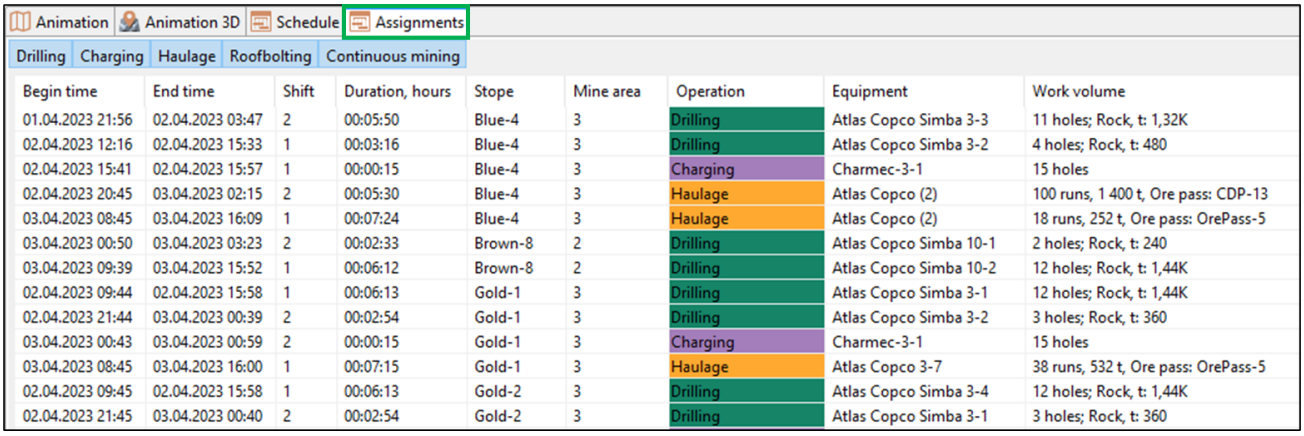
By clicking the buttons with equipment type icons, the Gantt chart will display only the equipment of the selected types. The button allows you to display only the stopes of the selected mine area and the equipment operating in the selected mine area.

A group of buttons 03.04.2023 allows you to display the schedule for a specific date. The button enables this mode, the button lets you to select the date, the button scales the Gantt chart so that only the schedule for the specified date is shown.

2.2.4. Assignments

The **Assignments** table contains a list of all operations performed by the equipment. For each operation, the following information is shown:

- **Start** and **end time** of the operation
- **Shift** number in which the operation was completed
- The **duration** of the operation
- The **stope** where the operation was performed
- The **mine area** to which the stope belongs
- **Equipment** that performed the operation
- The **work volume** completed (number of drilled/charged holes, number of trips, amount of hauled rock mass, etc.)
- **Final offset, m** — the distance from the start of the stope at which the operation ended



Begin time	End time	Shift	Duration, hours	Stope	Mine area	Operation	Equipment	Work volume
01.04.2023 21:56	02.04.2023 03:47	2	00:05:50	Blue-4	3	Drilling	Atlas Copco Simba 3-3	11 holes; Rock, t: 1,32K
02.04.2023 12:16	02.04.2023 15:33	1	00:03:16	Blue-4	3	Drilling	Atlas Copco Simba 3-2	4 holes; Rock, t: 480
02.04.2023 15:41	02.04.2023 15:57	1	00:00:15	Blue-4	3	Charging	Charmec-3-1	15 holes
02.04.2023 20:45	03.04.2023 02:15	2	00:05:30	Blue-4	3	Haulage	Atlas Copco (2)	100 runs, 1 400 t, Ore pass: CDP-13
03.04.2023 08:45	03.04.2023 16:09	1	00:07:24	Blue-4	3	Haulage	Atlas Copco (2)	18 runs, 252 t, Ore pass: OrePass-5
03.04.2023 00:50	03.04.2023 03:23	2	00:02:33	Brown-8	2	Drilling	Atlas Copco Simba 10-1	2 holes; Rock, t: 240
03.04.2023 09:39	03.04.2023 15:52	1	00:06:12	Brown-8	2	Drilling	Atlas Copco Simba 10-2	12 holes; Rock, t: 1,44K
02.04.2023 09:44	02.04.2023 15:58	1	00:06:13	Gold-1	3	Drilling	Atlas Copco Simba 3-1	12 holes; Rock, t: 1,44K
02.04.2023 21:44	03.04.2023 00:39	2	00:02:54	Gold-1	3	Drilling	Atlas Copco Simba 3-2	3 holes; Rock, t: 360
03.04.2023 00:43	03.04.2023 00:59	2	00:00:15	Gold-1	3	Charging	Charmec-3-1	15 holes
03.04.2023 08:45	03.04.2023 16:00	1	00:07:15	Gold-1	3	Haulage	Atlas Copco 3-7	38 runs, 532 t, Ore pass: OrePass-5
02.04.2023 09:45	02.04.2023 15:58	1	00:06:13	Gold-2	3	Drilling	Atlas Copco Simba 3-4	12 holes; Rock, t: 1,44K
02.04.2023 21:45	03.04.2023 00:40	2	00:02:54	Gold-2	3	Drilling	Atlas Copco Simba 3-1	3 holes; Rock, t: 360

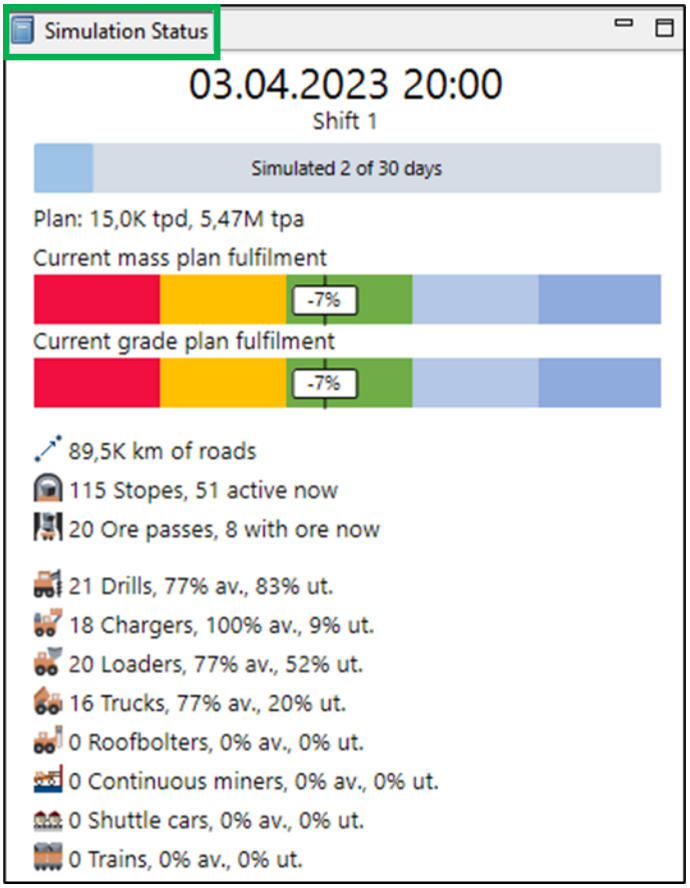
The user can choose to display only specific types of tasks in the table by clicking the corresponding buttons in the top toolbar of the **Assignments** window: drilling, charging, hauling, roofbolting, continuous mining, and scaling.

2.3. Statistical information

2.3.1. Simulation status

On the left side of the Simulation view, there is the **Simulation Status** panel, which displays general information about the progress of the simulation experiment:

- Current model date and time
- Current shift number
- Number of simulated days
- Daily and annual production targets
- Percentage of production target achieved by mass
- Percentage of production target achieved by ore grade
- Total length of roads in km
- Total number of stopes in the scenario and the number currently active
- Number of ore passes and number of ore passes containing ore
- Number of equipment units, their availability (av.) and utilization rate (ut.).



2.3.2. Summary statistics

The **Summary statistics** table displays the key statistical indicators of the simulation results:

- Total amount of mined ore mass, t
- Cumulative amount of mined production tons
- Planned cumulative ore production, t
- Deviation from the ore production plan, %
- Cumulative amount of development tons
- Development plan cumulative, t
- Deviation from the development plan, %
- Cumulative amount of development m^3
- Development plan cumulative, m^3
- Substance cumulative, t
- Substance plan cumulative, t
- Substance deviation from the plan, %
- Average WIP in total and separately for production and development, t: average amount of material (ore, rock, etc.) between some two stages of mining. For example, the WIP of drilling is the amount of material for which drilling has started but has not been charged
- Average lead time in total and separately for production and development, days: the time required to mine a conditional ton of ore mass from drilling to haul on top

- Average daily production, t
- Availability and downtime share for LHDs, trucks, drill rigs, and charging machines, %
- Equipment utilization (UR) and effective UR by equipment type, %
- Total costs and separately fixed, variable, and capital costs, in USD
- Cost per ton, in USD

Summary Statistics

Total tons	108 104
Total production tons	108 104
Mining plan cumulative	141 221
Act/plan deviation	-23,45%
Total development tons	0
Development plan cumulative	0
Dev. act/plan deviation	+0,00%
Mined development cumula...	0
Development plan cumulati...	0
Substance cumulative	5 405
Substance plan cumulative	7 061
Substance deviation	-23,45%
Average WIP, tonnes	64 464,60
Average lead time, days	4,27
Average production WIP, to...	64 465
Average production lead tim...	4,27
Average development WIP, t...	0,00
Average development lead ti...	0,00
Avg. tonnes hauled per day, t	11 482,45
Loaders availability, %	79,92%
Trucks availability, %	80,13%
Drills availability, %	80,34%
Chargers availability, %	100,00%
Loaders lost time, %	11,66%
Trucks lost time, %	46,62%
Drills lost time, %	0,00%
Chargers lost time, %	0,00%
Loaders utilization, %	71,19%
Trucks utilization, %	44,61%
Drills Utilization, %	51,23%
Chargers utilization, %	3,88%
Loaders effective utilization, %	62,89%
Trucks effective utilization, %	23,82%
Drills effective utilization, %	51,23%
Chargers effective utilization...	3,88%
Total costs, USD	0,00
Fixed costs, USD	0,00
Variable costs, USD	0,00
Capital costs, USD	0,00
Cost per ton, USD	0,00

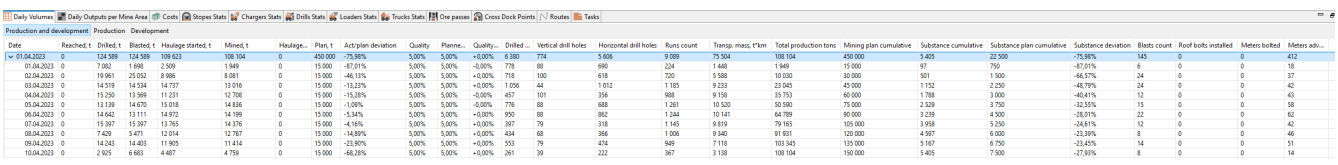
2.3.3. Daily volume stats

The **Daily Volume Stats** table shows the daily volumes of ore mass at different stages of its production:

- Reached ore mass (ore mass in stopes, access to which is open)
- Drilled ore mass
- Blasted ore mass
- Ore mass loaded to loaders
- Ore mass is unloaded by loaders and trucks to the ore passes
- Ore mass loaded to trains
- Ore mass unloaded from trains to the ore passes

It also displays production indicators such as:

- Daily planned ore mass production
- Deviation of the simulated production volume from the plan
- Simulated daily ore quality (percentage of substance)
- Planned daily ore quality (percentage of substance)
- Deviation of simulated ore quality from the plan
- Total number of drilled holes, and separately vertical and horizontal holes drilled
- Number of LHD/truck runs per day
- Daily haulage volume in tonne-kilometers
- Simulated cumulative ore mass production
- Planned cumulative ore mass production
- Simulated cumulative substance production
- Planned cumulative substance production
- Deviation from the substance production plan
- Number of blasts
- Number of roof bolts installed
- Total meters of installed rooof bolts
- Total length of advancement, m

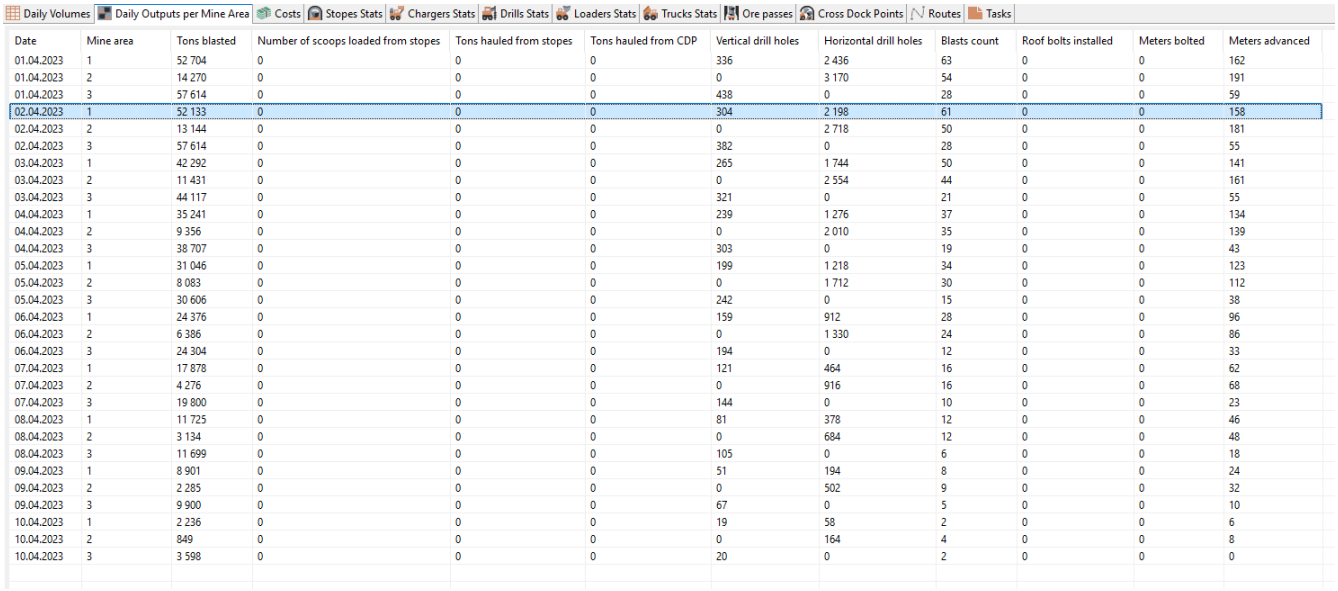


Date	Reached, t	Drilled, t	Blasted, t	Haulage started, t	Mined, t	Haulage...	Plan, t	Act/plan deviation	Quality	Planne...	Quality...	Drilled ...	Vertical drill holes	Horizontal drill holes	Runs count	Transp. mass, t*km	Total production tons	Mining plan cumulative	Substance cumulative	Substance plan cumulative	Substance deviation	Blasts count	Roof bolts installed	Meters bolted	Meters adv...
01.04.2023	0	124 589	124 589	109 623	108 104	0	450 000	-75,98%	5,00%	5,00%	+0,00%	6 380	774	5 606	9 089	75 504	108 104	450 000	5 405	22 500	-75,98%	145	0	0	412
01.04.2023	0	7 082	1 698	2 509	1 949	0	15 000	-87,01%	5,00%	5,00%	-0,00%	778	88	690	224	1 440	1 949	15 000	97	750	-87,01%	6	0	0	18
02.04.2023	0	19 961	25 052	8 986	8 081	0	15 000	-46,13%	5,00%	5,00%	+0,00%	718	100	618	720	5 588	10 030	30 000	501	1 500	-66,57%	24	0	0	37
03.04.2023	0	14 519	14 534	14 737	13 016	0	15 000	-13,23%	5,00%	5,00%	+0,00%	1 056	44	1 012	1 185	9 233	23 045	45 000	1 152	2 250	-48,79%	24	0	0	42
04.04.2023	0	15 250	13 569	11 231	12 708	0	15 000	-15,28%	5,00%	5,00%	-0,00%	457	101	356	988	9 158	35 753	60 000	1 788	3 000	-40,41%	12	0	0	43
05.04.2023	0	13 139	14 670	15 018	14 836	0	15 000	-1,09%	5,00%	5,00%	-0,00%	776	88	688	1 261	10 520	50 590	75 000	2 529	3 750	-32,55%	15	0	0	58
06.04.2023	0	14 642	13 111	14 972	14 199	0	15 000	-5,34%	5,00%	5,00%	+0,00%	950	88	862	1 244	10 141	64 789	90 000	3 239	4 500	-28,01%	22	0	0	62
07.04.2023	0	15 397	15 397	13 765	14 376	0	15 000	-4,16%	5,00%	5,00%	+0,00%	397	79	318	1 145	9 819	79 165	105 000	3 958	5 250	-24,61%	12	0	0	42
08.04.2023	0	7 429	5 471	12 014	12 767	0	15 000	-14,89%	5,00%	5,00%	+0,00%	434	68	366	1 006	9 340	91 931	120 000	4 597	6 000	-23,39%	8	0	0	46
09.04.2023	0	14 243	14 403	11 905	11 414	0	15 000	-23,90%	5,00%	5,00%	+0,00%	553	79	474	949	7 118	103 345	135 000	5 167	6 750	-23,45%	14	0	0	51
10.04.2023	0	2 925	6 683	4 487	4 759	0	15 000	-68,28%	5,00%	5,00%	+0,00%	261	39	222	367	3 138	108 104	150 000	5 405	7 500	-27,93%	8	0	0	14

2.3.4. Daily outputs by mine areas

The **Daily outputs by mine areas** table provides detailed daily statistics for mine areas:

- Amount of blasted rock mass, t
- Number of scoops loaded from stopes
- Amount of ore mass hauled out of the stopes, t
- Amount of ore mass hauled from Cross-Dock Points (CDP), t
- Number of drilled vertical holes
- Number of drilled horizontal holes
- Number of blasts
- Number of roof bolts installed
- Total meters of installed roof bolts
- Total length of advancement, m

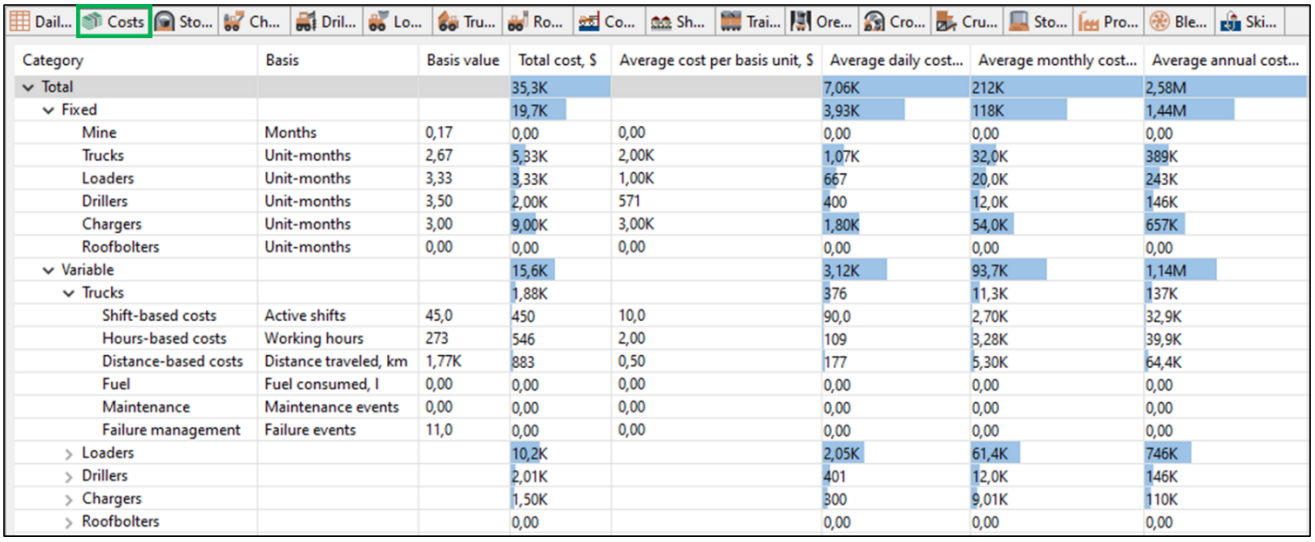


Daily Volumes | Daily Outputs per Mine Area | Costs | Stopes Stats | Chargers Stats | Drills Stats | Loaders Stats | Trucks Stats | Ore passes | Cross Dock Points | Routes | Tasks

Date	Mine area	Tons blasted	Number of scoops loaded from stopes	Tons hauled from stopes	Tons hauled from CDP	Vertical drill holes	Horizontal drill holes	Blasts count	Roof bolts installed	Meters bolted	Meters advanced
01.04.2023	1	52 704	0	0	0	336	2 436	63	0	0	162
01.04.2023	2	14 270	0	0	0	0	3 170	54	0	0	191
01.04.2023	3	57 614	0	0	0	438	0	28	0	0	59
02.04.2023	1	52 133	0	0	0	304	2 198	61	0	0	158
02.04.2023	2	13 144	0	0	0	0	2 718	50	0	0	181
02.04.2023	3	57 614	0	0	0	382	0	28	0	0	55
03.04.2023	1	42 292	0	0	0	265	1 744	50	0	0	141
03.04.2023	2	11 431	0	0	0	0	2 554	44	0	0	161
03.04.2023	3	44 117	0	0	0	321	0	21	0	0	55
04.04.2023	1	35 241	0	0	0	239	1 276	37	0	0	134
04.04.2023	2	9 356	0	0	0	0	2 010	35	0	0	139
04.04.2023	3	38 707	0	0	0	303	0	19	0	0	43
05.04.2023	1	31 046	0	0	0	199	1 218	34	0	0	123
05.04.2023	2	8 083	0	0	0	0	1 712	30	0	0	112
05.04.2023	3	30 606	0	0	0	242	0	15	0	0	38
06.04.2023	1	24 376	0	0	0	159	912	28	0	0	96
06.04.2023	2	6 386	0	0	0	0	1 330	24	0	0	86
06.04.2023	3	24 304	0	0	0	194	0	12	0	0	33
07.04.2023	1	17 878	0	0	0	121	464	16	0	0	62
07.04.2023	2	4 276	0	0	0	0	916	16	0	0	68
07.04.2023	3	19 800	0	0	0	144	0	10	0	0	23
08.04.2023	1	11 725	0	0	0	81	378	12	0	0	46
08.04.2023	2	3 134	0	0	0	0	684	12	0	0	48
08.04.2023	3	11 699	0	0	0	105	0	6	0	0	18
09.04.2023	1	8 901	0	0	0	51	194	8	0	0	24
09.04.2023	2	2 285	0	0	0	0	502	9	0	0	32
09.04.2023	3	9 900	0	0	0	67	0	5	0	0	10
10.04.2023	1	2 236	0	0	0	19	58	2	0	0	6
10.04.2023	2	849	0	0	0	0	164	4	0	0	8
10.04.2023	3	3 598	0	0	0	20	0	2	0	0	0

2.3.5. Costs

The **Costs** table contains information about costs by types of costs and types of equipment.



Dail... | Costs | Sto... | Ch... | Dril... | Lo... | Tru... | Ro... | Co... | Sh... | Trai... | Ore... | Cro... | Cru... | Sto... | Pro... | Ble... | Ski...

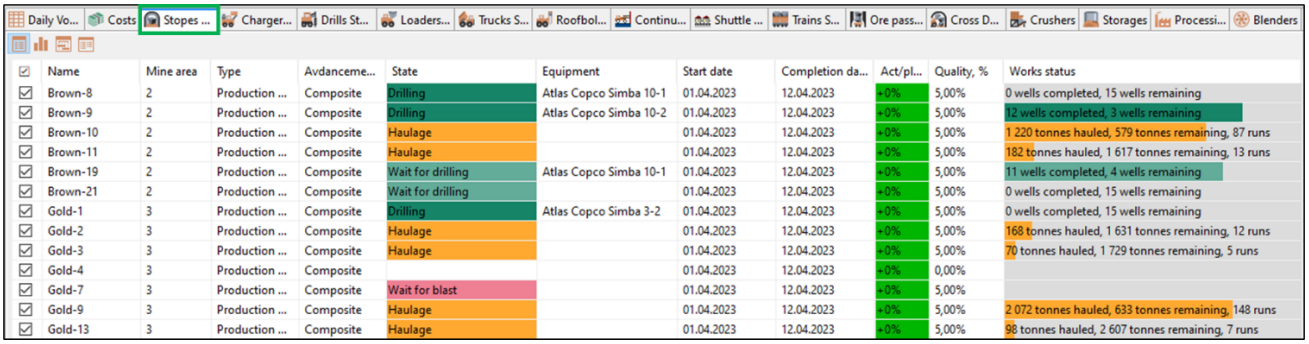
Category	Basis	Basis value	Total cost, $	Average cost per basis unit, $	Average daily cost...	Average monthly cost...	Average annual cost...
Total			35,3K		7,06K	212K	2,58M
Fixed			19,7K		3,93K	118K	1,44M
Mine	Months	0,17	0,00	0,00	0,00	0,00	0,00
Trucks	Unit-months	2,67	5,33K	2,00K	1,07K	32,0K	389K
Loaders	Unit-months	3,33	3,33K	1,00K	667	20,0K	243K
Drillers	Unit-months	3,50	2,00K	571	400	12,0K	146K
Chargers	Unit-months	3,00	9,00K	3,00K	1,80K	54,0K	657K
Roofbolters	Unit-months	0,00	0,00	0,00	0,00	0,00	0,00
Variable			15,6K		3,12K	93,7K	1,14M
Trucks			1,88K		376	11,3K	137K
Shift-based costs	Active shifts	45,0	450	10,0	90,0	2,70K	32,9K
Hours-based costs	Working hours	273	546	2,00	109	3,28K	39,9K
Distance-based costs	Distance traveled, km	1,77K	883	0,50	177	5,30K	64,4K
Fuel	Fuel consumed, l	0,00	0,00	0,00	0,00	0,00	0,00
Maintenance	Maintenance events	0,00	0,00	0,00	0,00	0,00	0,00
Failure management	Failure events	11,0	0,00	0,00	0,00	0,00	0,00
Loaders			10,2K		2,05K	61,4K	746K
Drillers			2,01K		401	12,0K	146K
Chargers			1,50K		300	9,01K	110K
Roofbolters			0,00		0,00	0,00	0,00

The table displays:

- Fixed costs total and by type of equipment
- Number of used equipment-months by types of equipment
    - Average costs per equipment unit by type for the entire simulation period/ average per day, average monthly/ average annual
- Variable costs by types of equipment with breakdown:
    - Shift-based costs
    - Hours-based costs
    - Distance-based costs
    - Fuel
    - Maintenance
    - Failure management
- Capital costs total and by type of equipment

2.3.6. Stopes stats

The **Stopes stats** table shows data on the state of stopes at each moment.



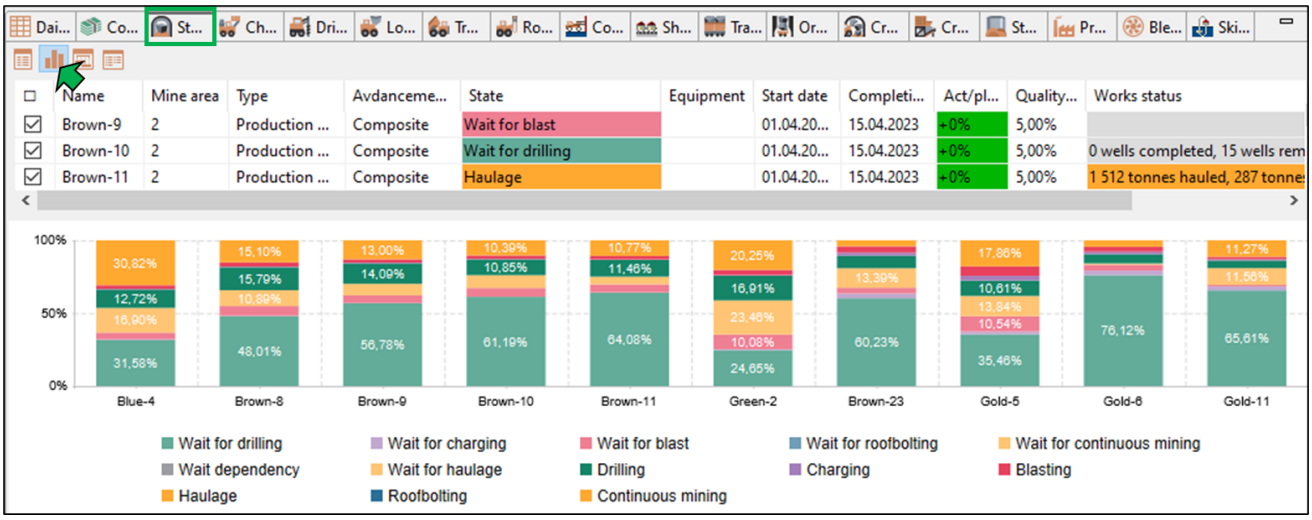
Name	Mine area	Type	Avdanceme...	State	Equipment	Start date	Completion da...	Act/pl...	Quality, %	Works status
Brown-8	2	Production ...	Composite	Drilling	Atlas Copco Simba 10-1	01.04.2023	12.04.2023	+0%	5,00%	0 wells completed, 15 wells remaining
Brown-9	2	Production ...	Composite	Drilling	Atlas Copco Simba 10-2	01.04.2023	12.04.2023	+0%	5,00%	12 wells completed, 3 wells remaining
Brown-10	2	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	1 220 tonnes hauled, 579 tonnes remaining, 87 runs
Brown-11	2	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	182 tonnes hauled, 1 617 tonnes remaining, 13 runs
Brown-19	2	Production ...	Composite	Wait for drilling	Atlas Copco Simba 10-1	01.04.2023	12.04.2023	+0%	5,00%	11 wells completed, 4 wells remaining
Brown-21	2	Production ...	Composite	Wait for drilling		01.04.2023	12.04.2023	+0%	5,00%	0 wells completed, 15 wells remaining
Gold-1	3	Production ...	Composite	Drilling	Atlas Copco Simba 3-2	01.04.2023	12.04.2023	+0%	5,00%	0 wells completed, 15 wells remaining
Gold-2	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	168 tonnes hauled, 1 631 tonnes remaining, 12 runs
Gold-3	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	70 tonnes hauled, 1 729 tonnes remaining, 5 runs
Gold-4	3	Production ...	Composite			01.04.2023	12.04.2023	+0%	0,00%	
Gold-7	3	Production ...	Composite	Wait for blast		01.04.2023	12.04.2023	+0%	5,00%	
Gold-9	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	2 072 tonnes hauled, 633 tonnes remaining, 148 runs
Gold-13	3	Production ...	Composite	Haulage		01.04.2023	12.04.2023	+0%	5,00%	98 tonnes hauled, 2 607 tonnes remaining, 7 runs

The following is shown for each stope:

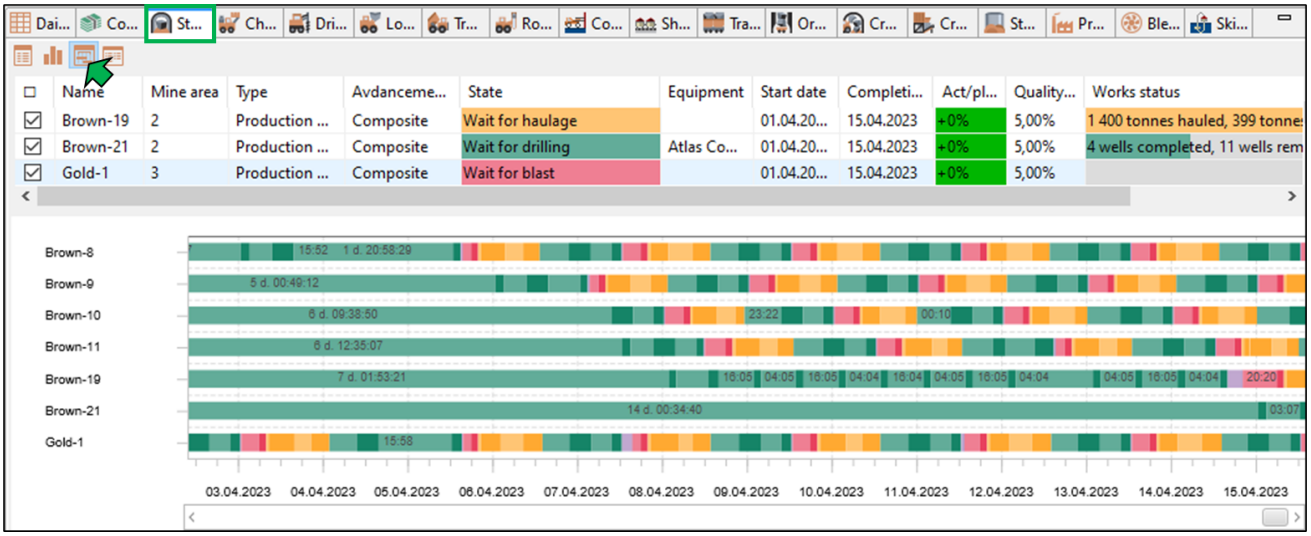
- Mine area to which the stope belongs
- Type (production or development)
- Advancement Type (excavation, cleaning, etc.)
- Current state of the stope (wait for drilling, drilling, wait for charging, charging, etc.)
- Start and completion date
- Duration of state
- Simulated amount of removed ore mass in tons
- Number of drilled vertical hole-meters
- Number of drilled horizontal hole-meters
- Total advancement length of the stopes, m
- Amount of remaining ore mass in tonnes and m^3
- Planned ore mass to be removed, t

- Percentage deviation from the plan
- Ore mass quality in the stope (substance grade)
- Ore mass density in the stope
- Work status: volume of completed and remaining work in the stope (number of drilled and remaining holes, tonnes of hauled and remaining rock mass, etc.)

The button  in the upper right corner of the table opens the bar chart of stopes stats.



The button  in the upper right corner of the table opens the Gantt chart of stopes statistics.



Clicking the  button in the upper-right corner of the table opens a table with detailed information on stope states for the entire simulation period.

Name	Mine area	State	Begin time	End time	Duration	Description	End offset, m	Equipment
Blue-2	3	Wait for drilling	01.04.2023 00:00	01.04.2023 09:44	09:44:23		0.0	
Blue-2	3	Drilling	01.04.2023 09:44	01.04.2023 16:18	06:34:34	Section #0, Ro...	40.0	Atlas Copco Si...
Blue-2	3	Wait for drilling	01.04.2023 16:18	01.04.2023 21:44	05:25:26		0.0	
Blue-2	3	Drilling	01.04.2023 21:44	02.04.2023 00:17	02:32:55	Section #0, Ro...	40.0	Atlas Copco Si...
Blue-2	3	Wait for charging	02.04.2023 00:17	02.04.2023 00:21	00:04:01		0.0	
Blue-2	3	Charging	02.04.2023 00:21	02.04.2023 00:37	00:15:59	15 wells	40.0	Charmec-3-1
Blue-2	3	Wait for blast	02.04.2023 00:37	02.04.2023 06:00	05:22:38		0.0	
Blue-2	3	Blasting	02.04.2023 06:00	02.04.2023 08:00	02:00:00		37.5	
Blue-2	3	Wait for haulage	02.04.2023 08:00	02.04.2023 08:45	00:45:00		0.0	
Blue-2	3	Haulage	02.04.2023 08:45	02.04.2023 17:00	08:15:00	0 runs, 588 ton...	40.0	Atlas Copco 3-2
Blue-2	3	Wait for haulage	02.04.2023 17:00	02.04.2023 20:45	03:45:00		0.0	
Blue-2	3	Haulage	02.04.2023 20:45	03.04.2023 05:00	08:15:00	0 runs, 588 ton...	40.0	Atlas Copco 3-1
Blue-2	3	Wait for haulage	03.04.2023 05:00	03.04.2023 08:45	03:45:00		0.0	
Blue-2	3	Haulage	03.04.2023 08:45	03.04.2023 17:00	08:15:00	0 runs, 532 ton...	40.0	Atlas Copco 3-9
Blue-2	3	Wait for haulage	03.04.2023 17:00	03.04.2023 20:45	03:45:00		0.0	
Blue-2	3	Haulage	03.04.2023 20:45	03.04.2023 21:56	01:11:45	0 runs, 91 ton...	37.5	Atlas Copco 3-2
Blue-2	3	Wait for drilling	03.04.2023 21:56	03.04.2023 23:06	01:10:04		0.0	
Blue-2	3	Drilling	03.04.2023 23:06	04.04.2023 04:13	05:06:41	Section #1, Ro...	37.5	Atlas Copco Si...
Blue-2	3	Wait for drilling	04.04.2023 04:13	04.04.2023 09:44	05:30:50		0.0	
Blue-2	3	Drilling	04.04.2023 09:44	04.04.2023 13:45	04:00:47	Section #1, Ro...	37.5	Atlas Copco Si...
Blue-2	3	Wait for charging	04.04.2023 13:45	04.04.2023 13:49	00:04:01		0.0	
Blue-2	3	Charging	04.04.2023 13:49	04.04.2023 14:05	00:15:59	15 wells	37.5	Charmec-3-2
Blue-2	3	Wait for blast	04.04.2023 14:05	04.04.2023 18:00	03:54:48		0.0	
Blue-2	3	Blasting	04.04.2023 18:00	04.04.2023 20:00	02:00:00		35.0	
Blue-2	3	Wait for haulage	04.04.2023 20:00	04.04.2023 20:45	00:45:00		0.0	

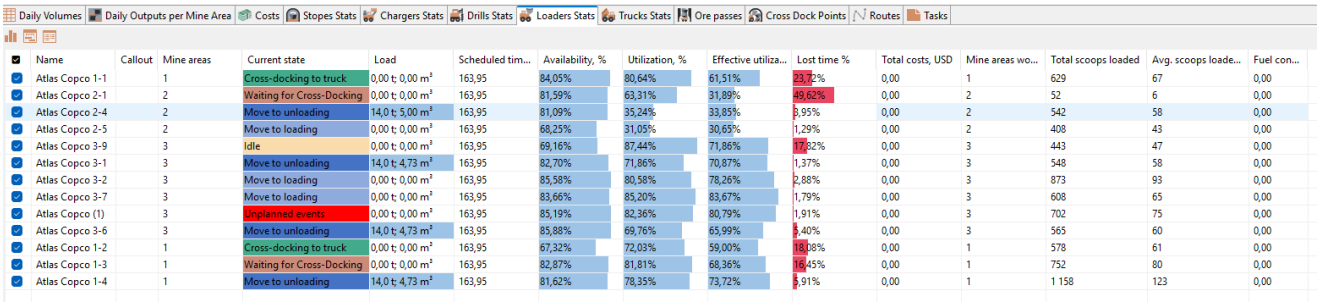
2.3.7. Equipment stats

Separate tables are provided for each equipment type, displaying the status and general information for all equipment units, including:

- The mine area to which the equipment unit is assigned
- Current state (moving, performing a task, idle, etc.)
- Equipment availability, % – the ratio of time during which the equipment was available for work (according to the schedule and planned downtime) to the total in-shift time. For example, an LHD operates two 10-hour shifts. Its in-shift time is 20 hours. Each shift includes a 0.5-hour lunch break, and at the start of the first shift it has 2 hours of planned maintenance. Thus, the available time for the LHD on that day is: *20 − 0.5×2 − 2 = 17* hours, and availability is *17/20 = 85%*.
- Equipment utilization rate, % – the ratio of time during which the equipment performed tasks to the total in-shift time. For example, the LHD operated for: 5 hours of travel, 3 hours of loading, 2 hours of unloading, and 1 hour waiting in queue at the ore pass. Total productive time *5 + 3 + 2 + 1 = 11* hours, so UR *11/20 = 55%*.
- Effective utilization rate, % – utilization excluding non-productive time. In the previous example: productive time excluding queue waiting *11 − 1 = 10* hours, so effective UR *10/20 = 50%*.
- Lost time, % – the ratio of non-productive time to total task execution time. In the example: productive time *11* hours, "lost" queue time *1* hour → downtime share *1/11 = 9%*.
- Costs for the equipment unit, USD
- List of mine areas in which the equipment unit operated during the simulation
- Additional information specific for each equipment type like **Total scoops loaded**, **Drilled wells** etc.

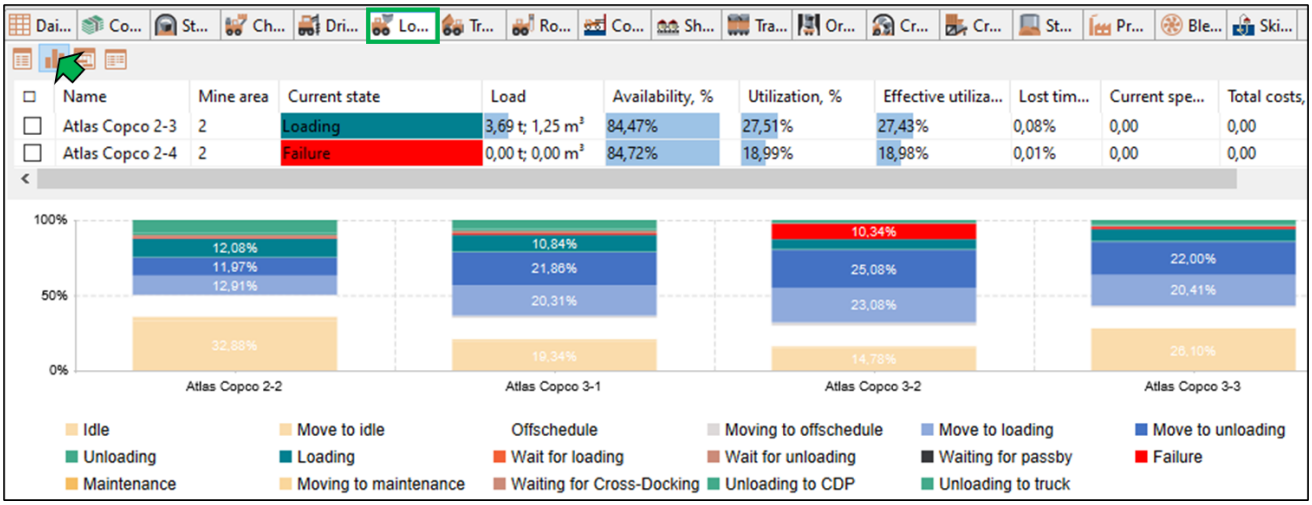
- Duel consumption by the unit, l

An example table for LHDs is shown below:

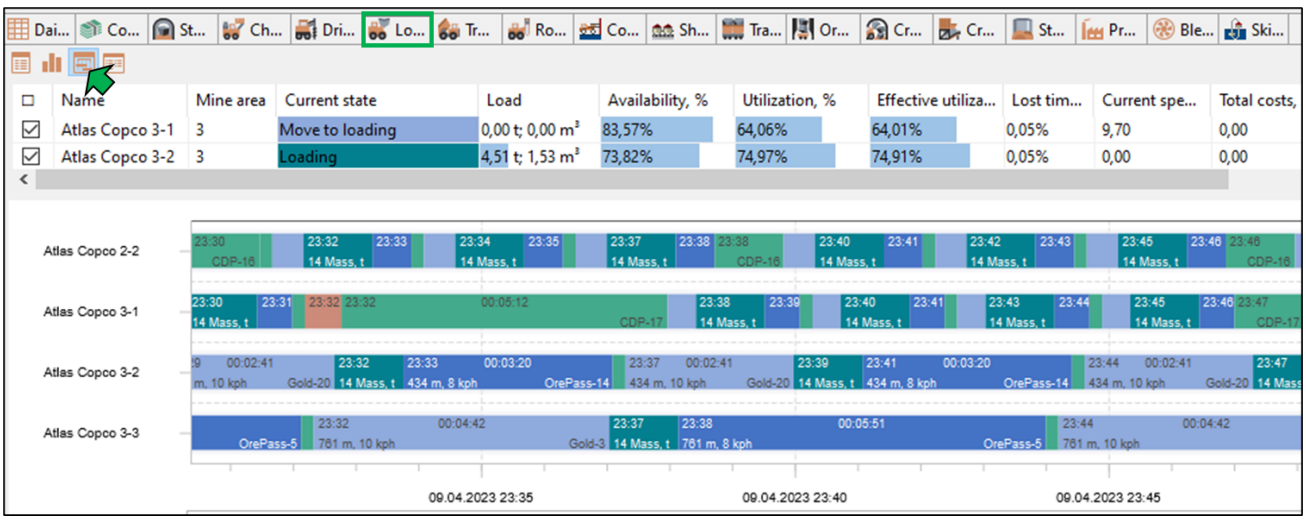


Name	Callout	Mine areas	Current state	Load	Scheduled tim...	Availability, %	Utilization, %	Effective utiliza...	Lost time %	Total costs, USD	Mine areas wo...	Total scoops loaded	Avg. scoops loade...	Fuel con...
Atlas Copco 1-1		1	Cross-docking to truck	0,00 t; 0,00 m³	163,95	84,05%	80,64%	61,51%	23,72%	0,00	1	629	67	0,00
Atlas Copco 2-1		2	Waiting for Cross-Docking	0,00 t; 0,00 m³	163,95	81,59%	63,31%	31,89%	49,62%	0,00	2	52	6	0,00
Atlas Copco 2-4		2	Move to unloading	14,0 t; 5,00 m³	163,95	81,09%	35,24%	33,85%	3,95%	0,00	2	542	58	0,00
Atlas Copco 2-5		2	Move to loading	0,00 t; 0,00 m³	163,95	68,25%	31,05%	30,65%	1,29%	0,00	2	408	43	0,00
Atlas Copco 3-9		3	Idle	0,00 t; 0,00 m³	163,95	69,16%	87,44%	71,86%	17,82%	0,00	3	443	47	0,00
Atlas Copco 3-1		3	Move to unloading	14,0 t; 4,73 m³	163,95	82,70%	71,86%	70,87%	1,37%	0,00	3	548	58	0,00
Atlas Copco 3-2		3	Move to loading	0,00 t; 0,00 m³	163,95	85,58%	80,58%	78,26%	2,88%	0,00	3	873	93	0,00
Atlas Copco 3-7		3	Move to loading	0,00 t; 0,00 m³	163,95	83,66%	85,20%	83,67%	1,79%	0,00	3	608	65	0,00
Atlas Copco (1)		3	Unplanned events	0,00 t; 0,00 m³	163,95	85,19%	82,36%	80,79%	1,91%	0,00	3	702	75	0,00
Atlas Copco 3-6		3	Move to unloading	14,0 t; 4,73 m³	163,95	85,88%	69,76%	65,99%	5,40%	0,00	3	565	60	0,00
Atlas Copco 1-2		1	Cross-docking to truck	0,00 t; 0,00 m³	163,95	67,32%	72,03%	59,00%	18,08%	0,00	1	578	61	0,00
Atlas Copco 1-3		1	Waiting for Cross-Docking	0,00 t; 0,00 m³	163,95	82,87%	81,81%	68,36%	16,45%	0,00	1	752	80	0,00
Atlas Copco 1-4		1	Move to unloading	14,0 t; 4,73 m³	163,95	81,62%	78,35%	73,72%	5,91%	0,00	1	1 158	123	0,00

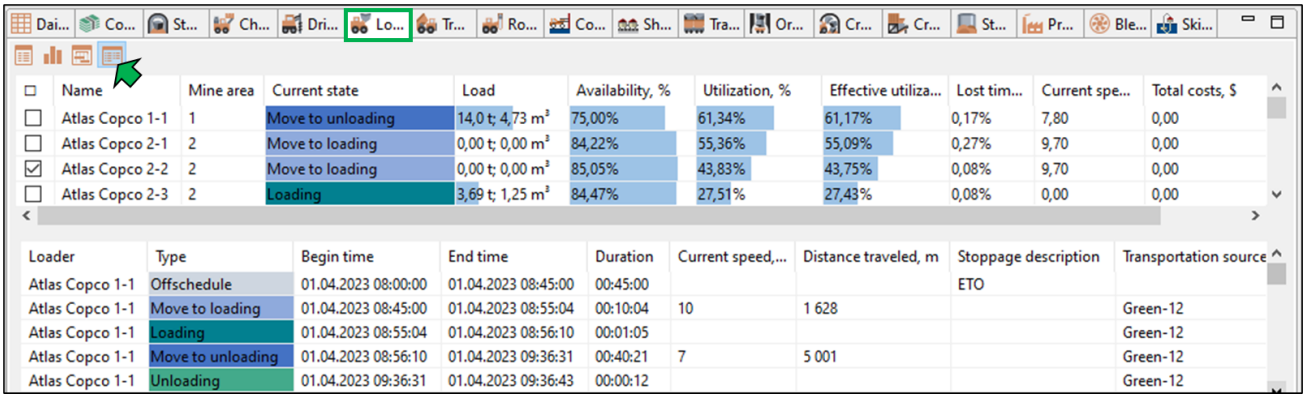
Clicking the button in the upper-right corner of the table opens the bar-chart view of equipment statistics.



Clicking the button opens the Gantt chart of equipment operations.



Clicking the button opens a table with detailed information on equipment states for the entire simulation.



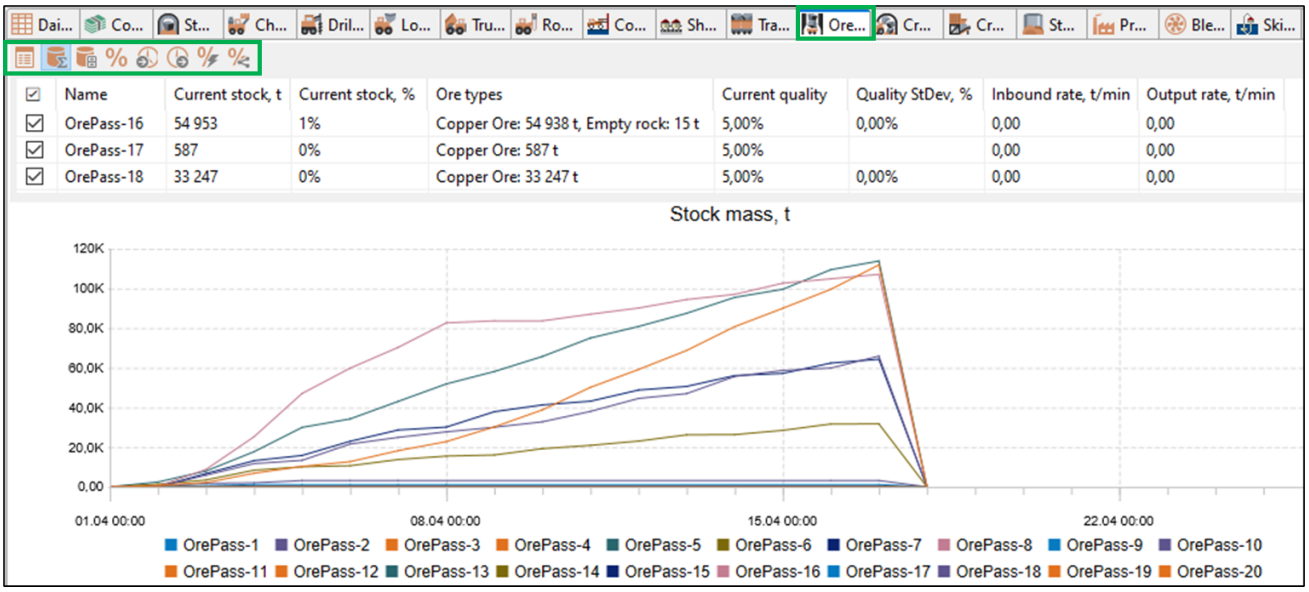
Name	Mine area	Current state	Load	Availability, %	Utilization, %	Effective utiliza...	Lost tim...	Current spe...	Total costs, $
Atlas Copco 1-1	1	Move to unloading	14,0 t; 4,73 m³	75,00%	61,34%	61,17%	0,17%	7,80	0,00
Atlas Copco 2-1	2	Move to loading	0,00 t; 0,00 m³	84,22%	55,36%	55,09%	0,27%	9,70	0,00
Atlas Copco 2-2	2	Move to loading	0,00 t; 0,00 m³	85,05%	43,83%	43,75%	0,08%	9,70	0,00
Atlas Copco 2-3	2	Loading	3,69 t; 1,25 m³	84,47%	27,51%	27,43%	0,08%	0,00	0,00

Loader	Type	Begin time	End time	Duration	Current speed,...	Distance traveled, m	Stoppage description	Transportation source
Atlas Copco 1-1	Offschedule	01.04.2023 08:00:00	01.04.2023 08:45:00	00:45:00			ETO	
Atlas Copco 1-1	Move to loading	01.04.2023 08:45:00	01.04.2023 08:55:04	00:10:04	10	1 628		Green-12
Atlas Copco 1-1	Loading	01.04.2023 08:55:04	01.04.2023 08:56:10	00:01:05				Green-12
Atlas Copco 1-1	Move to unloading	01.04.2023 08:56:10	01.04.2023 09:36:31	00:40:21	7	5 001		Green-12
Atlas Copco 1-1	Unloading	01.04.2023 09:36:31	01.04.2023 09:36:43	00:00:12				Green-12

2.3.8. Ore storage locations

In separate tables for ore passes, cross-dock points and storages information about their current states is displayed, such as fill level, ore types, ore quality, and more.

An example table showing ore pass states is presented below:



Name	Current stock, t	Current stock, %	Ore types	Current quality	Quality StDev, %	Inbound rate, t/min	Output rate, t/min
OrePass-16	54 953	1%	Copper Ore: 54 938 t, Empty rock: 15 t	5,00%	0,00%	0,00	0,00
OrePass-17	587	0%	Copper Ore: 587 t	5,00%		0,00	0,00
OrePass-18	33 247	0%	Copper Ore: 33 247 t	5,00%	0,00%	0,00	0,00

For each ore pass, the following information is shown:

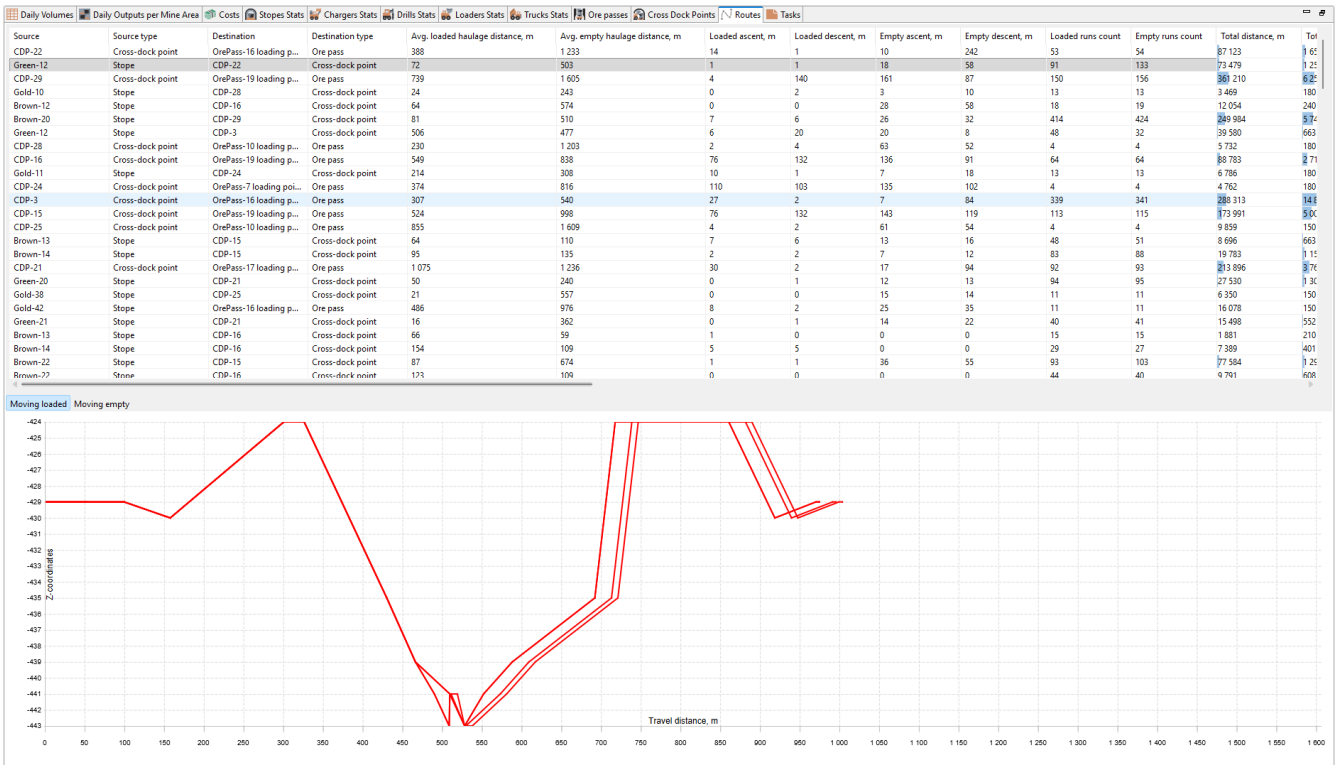
- **Callout** — allows you to display callout window for selected object
- **Mine area** to which the ore pass belongs
- **Capacity**, t
- **Current stock**, in tonnes and as % of capacity
- Amount of **ore types** contained in the ore pass by type
- Current ore **quality** in the ore pass, %
- **Standard deviation of ore quality** (StDev), %
- **Inbound rate** of ore mass into the ore pass, t/min
- **Output rate** of ore mass from the ore pass, t/min

The buttons on the toolbar of the **Ore Passes** window open individual charts showing:

- Ore mass stock in ore passes, in tons
- Volume of ore mass stock in ore passes, in m3
- Change in the quality of the ore mass, in %
- Rate of ore mass entering the ore pass, t/min
- Output rate of ore mass from the ore pass, t/min.
- Changes in the quality of ore fragments, %
- Variability of the content of useful substances by processing stages, %.

2.3.9. Routes

The **Routes** table displays the following data for each route:



- Source and Destination for the route, and its types
- Average haul distance loaded/empty, m
- Ascent loaded/empty, m
- Descent loaded/empty, m
- Number of loaded trips / return trips
- Total distance traveled, km
- Total tonnes hauled
- Total tonne-kilometers
- Average travel time loaded/empty, min
- Average travel speed loaded/empty, km/h
- Duration of the full loading–hauling–unloading cycle, min

- Percentage of time spent loading / unloading / waiting
- Quality of material hauled on the route, %
- List of equipment types and units that performed trips along the route

For each route a Z-axis profile of the route is displayed for loaded and empty route leg.

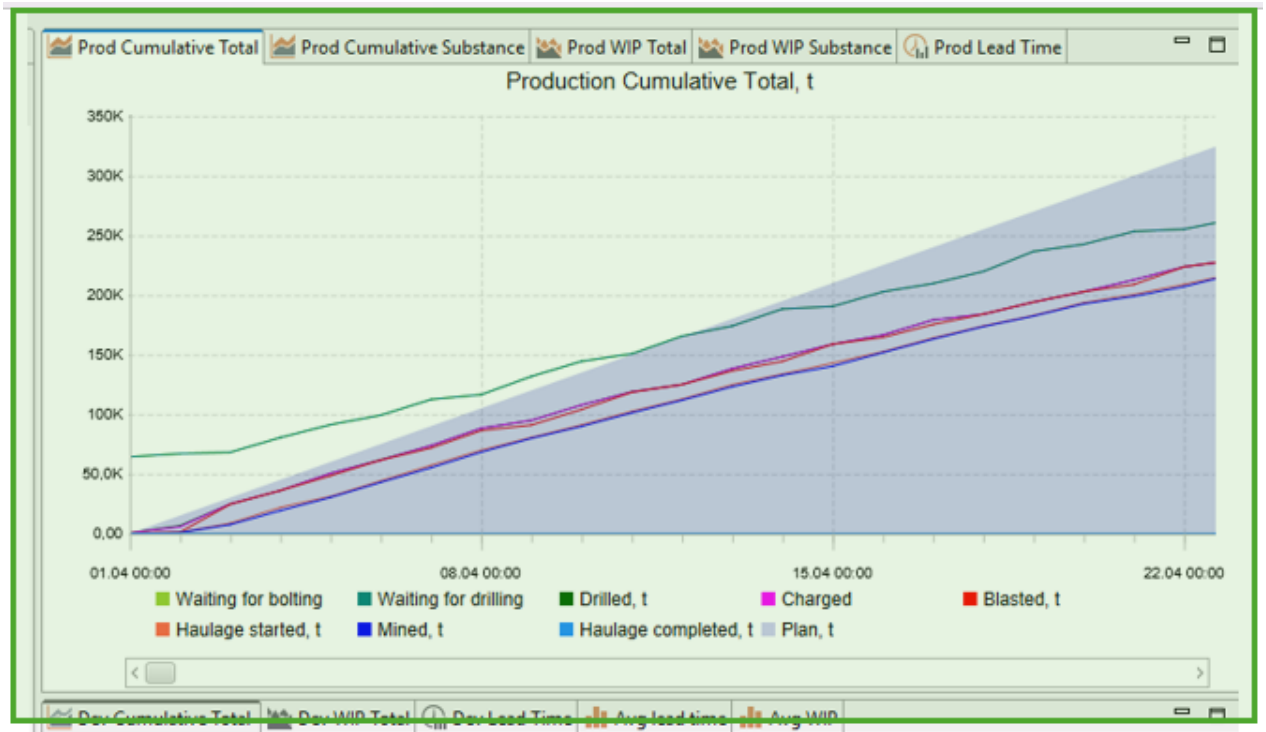
2.3.10. Tasks

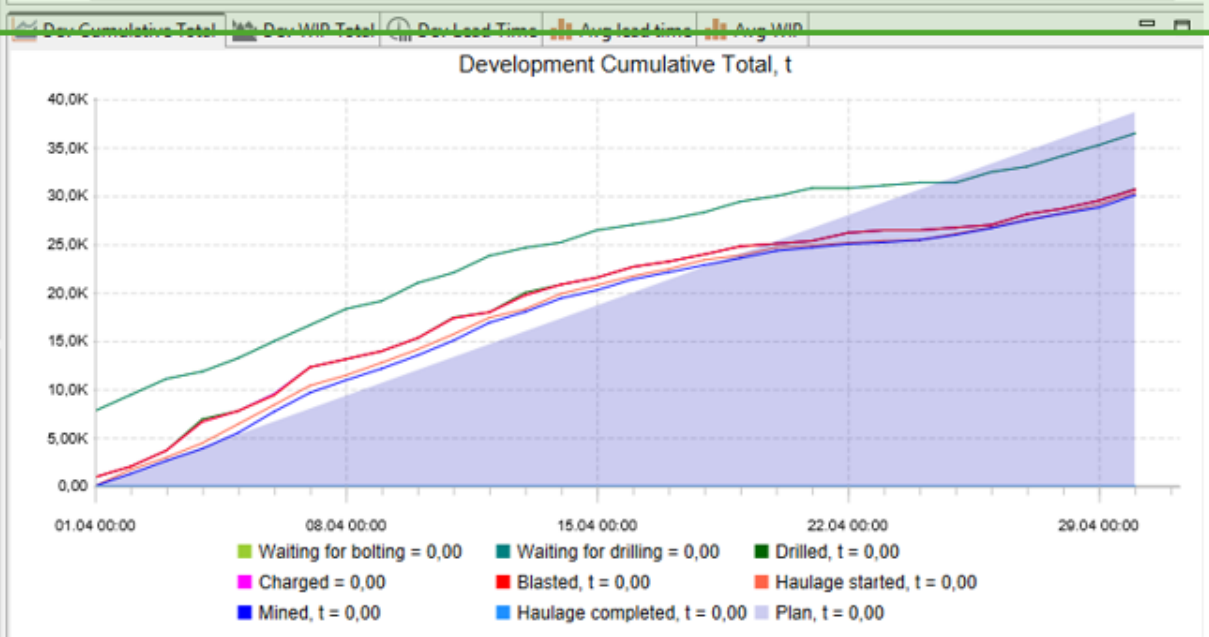
The **Tasks** table contains technical information on status of each current active task.

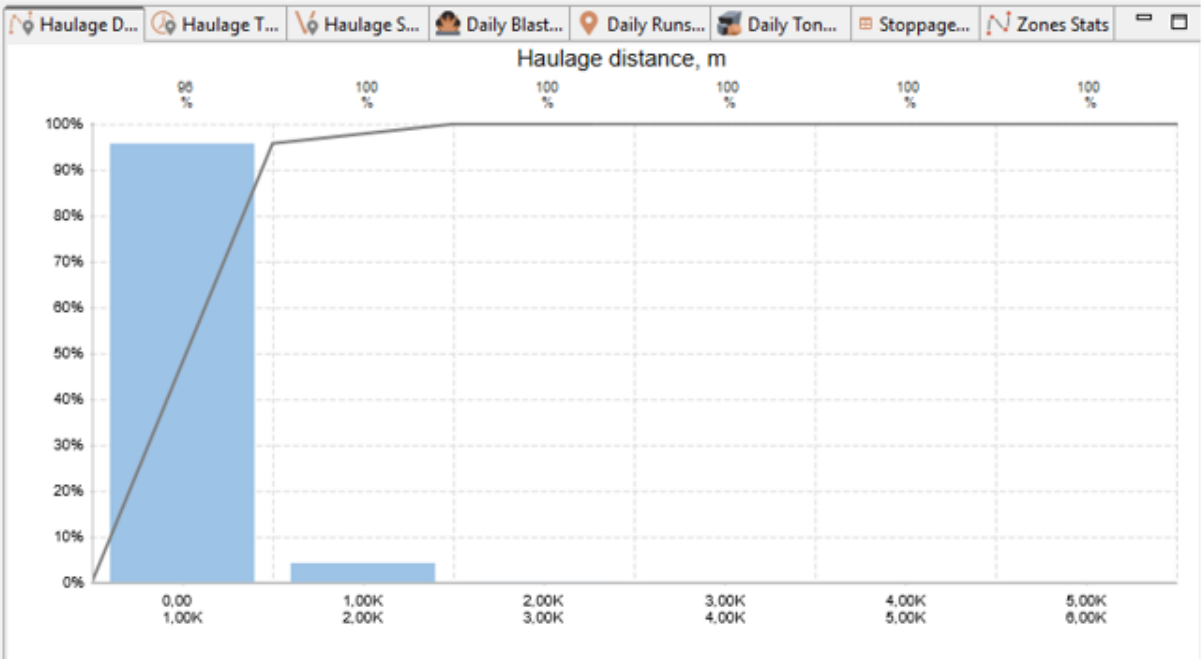
2.4. Graphs and charts

The MineTwin Underground visualization contains various graphs and charts for analyzing simulation results. By default, they are grouped into three windows on the right side of the screen.

2.4.1. Graphs for analysis of production


Prod Cumulative Total
Prod Cumulative Substance
Prod WIP Total
Prod WIP Substance
Prod Lead Time
Production Cumulative Total, t
350K
300K
250K
200K
150K
100K
50,0K
0,00
01.04 00:00
08.04 00:00
15.04 00:00
22.04 00:00
Waiting for bolting
Waiting for drilling
Drilled, t
Charged
Blasted, t
Haulage started, t
Mined, t
Haulage completed, t
Plan, t

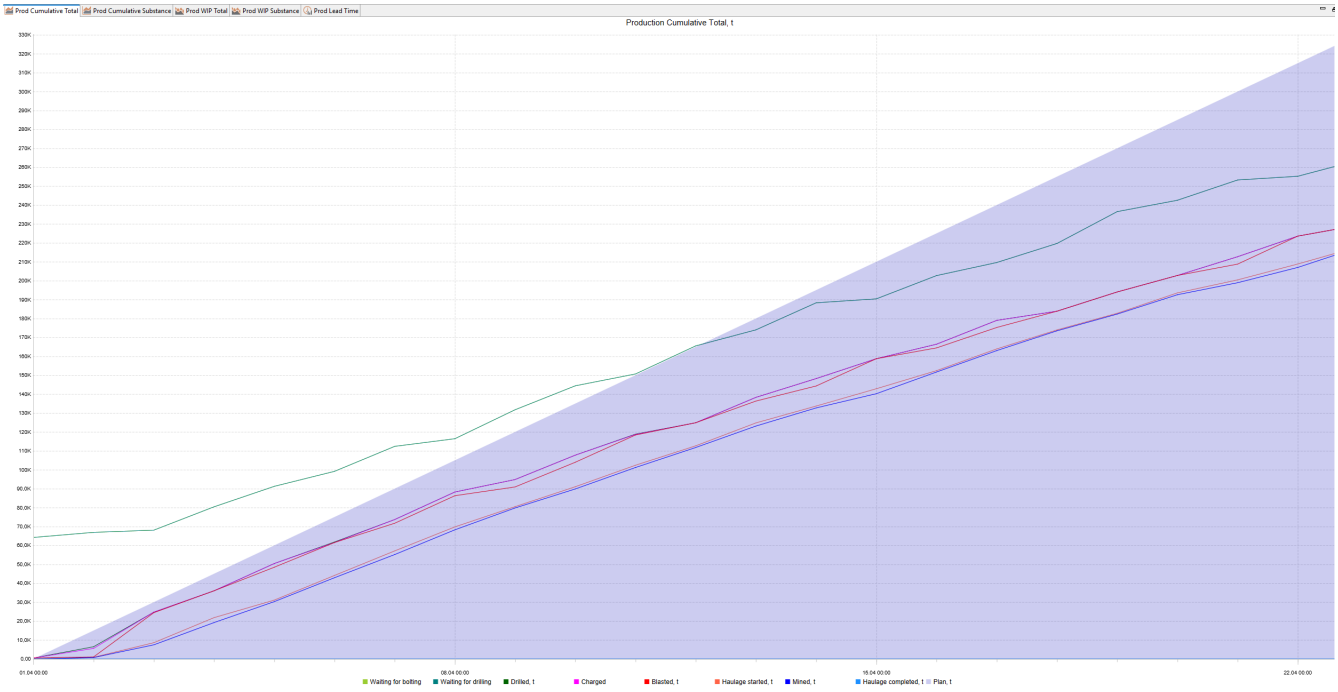

Development Cumulative Total, t
40,0K
35,0K
30,0K
25,0K
20,0K
15,0K
10,0K
5,00K
0,00
01.04 00:00
08.04 00:00
15.04 00:00
22.04 00:00
29.04 00:00
Waiting for bolting = 0,00
Waiting for drilling = 0,00
Drilled, t = 0,00
Charged = 0,00
Blasted, t = 0,00
Haulage started, t = 0,00
Mined, t = 0,00
Haulage completed, t = 0,00
Plan, t = 0,00


Haulage D...
Haulage T...
Haulage S...
Daily Blast...
Daily Runs...
Daily Ton...
Stoppage...
Zones Stats
Haulage distance, m
96 %
100 %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0,00
1,00K
2,00K
3,00K
4,00K
5,00K
6,00K

Several graphs in the upper right window are dedicated to the production mining. They are:

2.4.2. Production Cumulative Total Chart

The **Production Cumulative Total** chart displays the cumulative progress of mining operations over time, showing the total amount of ore mass (in tonnes) that has passed through each stage of the mining cycle.



This chart helps track how much ore mass has been reached, bolted, drilled, charged, blasted, hauled, and mined relative to the production plan. It allows users to visually compare actual progress against planned targets.

Chart Elements:

- X-axis (horizontal): Timeline (dates and times of the simulation)
- Y-axis (vertical): Cumulative tonnage (t)

Lines and Areas

- **Waiting for bolting, t** — ore mass in stopes that have become accessible for bolting
- **Waiting for drilling, t** — ore mass in stopes that have become accessible for drilling
- **Drilled, t** — ore mass in stopes where drilling has been completed
- **Charged, t** — ore mass in stopes where charging has been completed
- **Blasted, t** — ore mass in stopes that have been blasted and are ready for hauling
- **Haulage started, t** — ore mass currently being hauled
- **Mined, t** — ore mass, that was considered as mined
- **Haulage completed, t** — ore mass that has been delivered to haulage destinations
- **Plan, t** (filled area) — cumulative planned production target

How to Use:

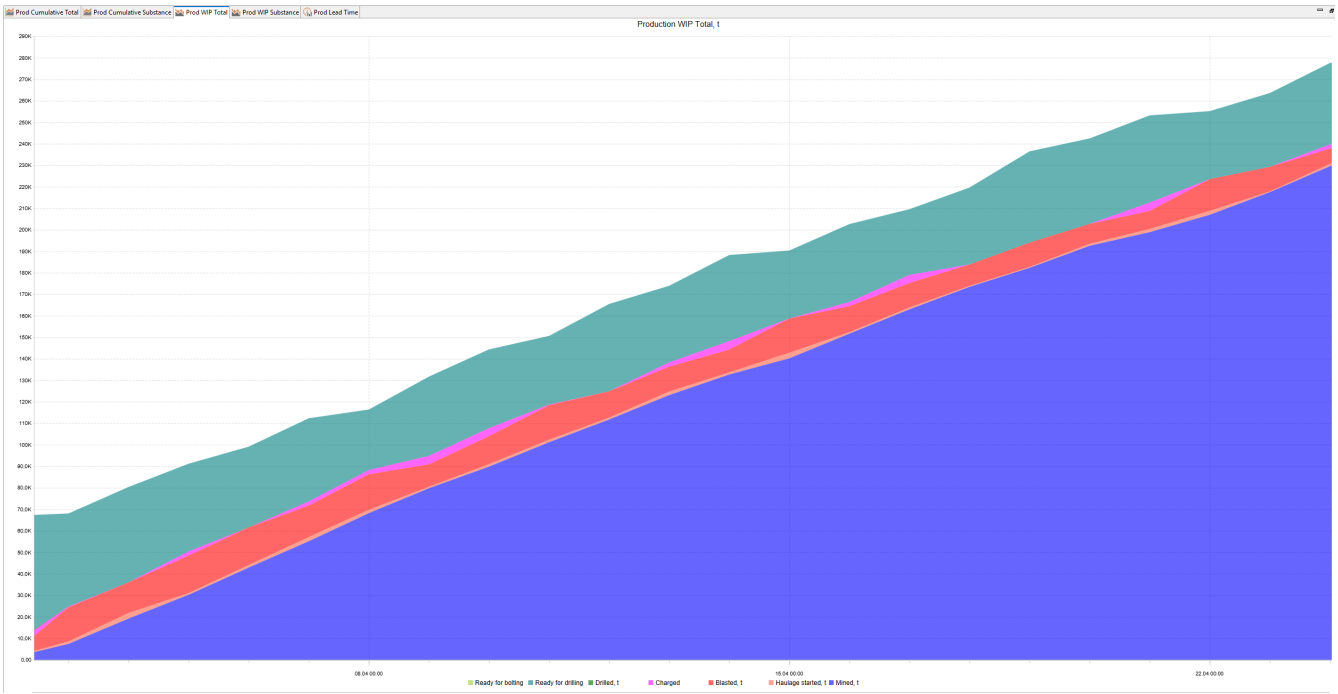
- Monitor the buildup of tonnage through each stage of the production cycle.
- Verify that actual production (mined/haulage completed) is following the planned trajectory.
- Identify bottlenecks: flat lines indicate inactive stages where no progress occurred during the period.
- Detect delays: if the mined line lags significantly behind the plan area, production is behind schedule.

2.4.3. Production Cumulative Substance Chart

The **Production Cumulative Substance** chart uses the same logic as **Production Cumulative Total** chart but for useful material, contained in ore mass.

2.4.4. Production WIP Total Chart

The **Production WIP (Work In Progress) Total** chart shows the amount of ore mass (in tonnes) that is currently in progress at each stage of the mining cycle over time.



This chart helps analyze where ore mass is “accumulating” in the production process at any given moment. It shows how much ore mass is waiting at each stage — bolted, drilled, charged, blasted, or awaiting haulage — and helps identify production bottlenecks.

Chart Elements:

- X-axis (horizontal): Timeline (dates and times of the simulation)
- Y-axis (vertical): Amount of ore mass currently in progress (t)

Stacked Areas:

- **Ready for bolting, t** — ore mass in stopes that have become accessible but not yet bolted

- **Ready for drilling, t** — ore mass in stopes that have been bolted but not yet drilled
- **Drilled, t** — ore mass drilled but not yet charged
- **Charged, t** — ore mass charged but not yet blasted
- **Blasted, t** — ore mass blasted and awaiting haulage
- **Haulage started, t** — ore mass currently being hauled but is not yet considered as mined
- **Mined, t** — ore mass that was considered as mined, but which haulage is not yet completed

How to Use:

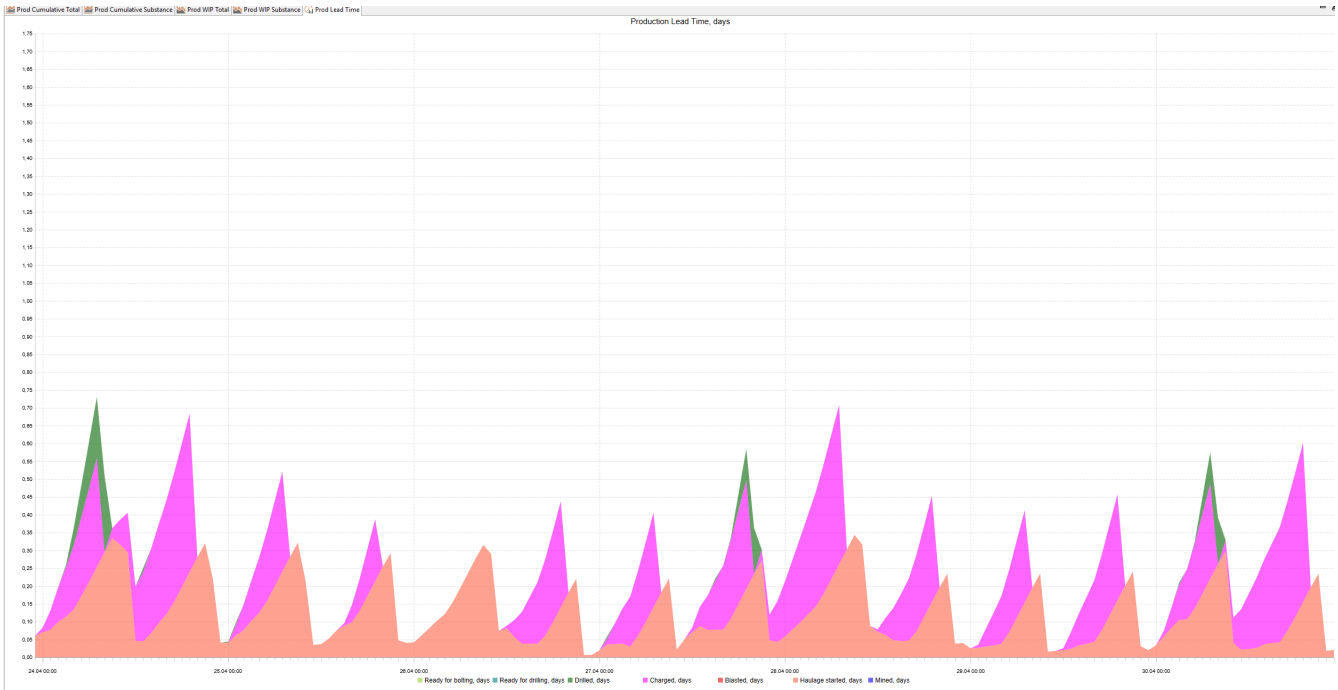
- Observe how material flows through different stages and where it accumulates.
- Detect production bottlenecks — if material builds up in one stage (for example, large red area = blasted but not hauled), it may indicate insufficient equipment capacity at the next stage.
- Verify process balance — steady material levels at all stages indicate a smooth production flow, while sharp spikes or drops show interruptions.
- Monitor the depletion of blasted material as it is gradually hauled away.

2.4.5. Production WIP Substance Chart

The **Production WIP Substance** chart uses the same logic as **Production WIP Total** chart but for useful material, contained in ore mass.

2.4.6. Production Lead Time Chart

The **Production Lead Time** chart shows how long ore mass (in days) spends in each stage of the mining process, calculated as how many days ore mass is staying in its current stage of the mining process at each point of time.



This chart helps analyze the overall efficiency of the production chain by showing how much time it takes for ore mass to pass through each stage — from becoming accessible to being hauled to the

final destination. It helps identify delays or bottlenecks that increase the total cycle time.

Chart Elements:

- X-axis (horizontal): Timeline (dates and times of the simulation)
- Y-axis (vertical): Lead time in days

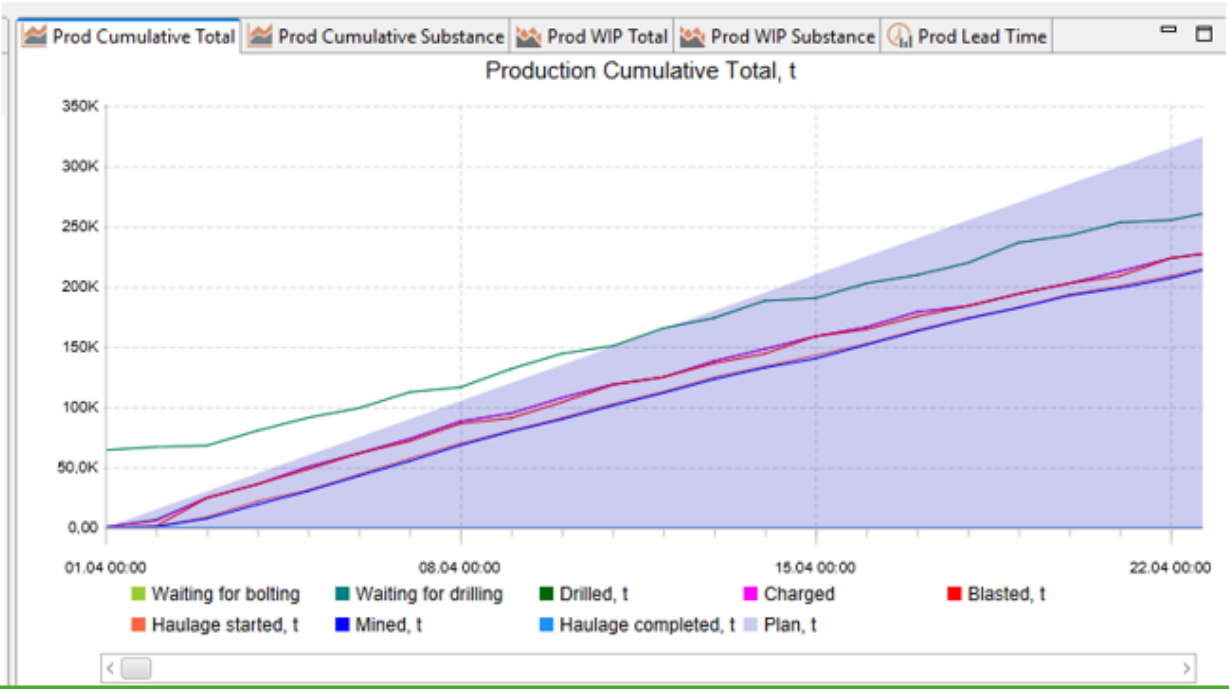
Stacked Areas (lead time contribution by stage):

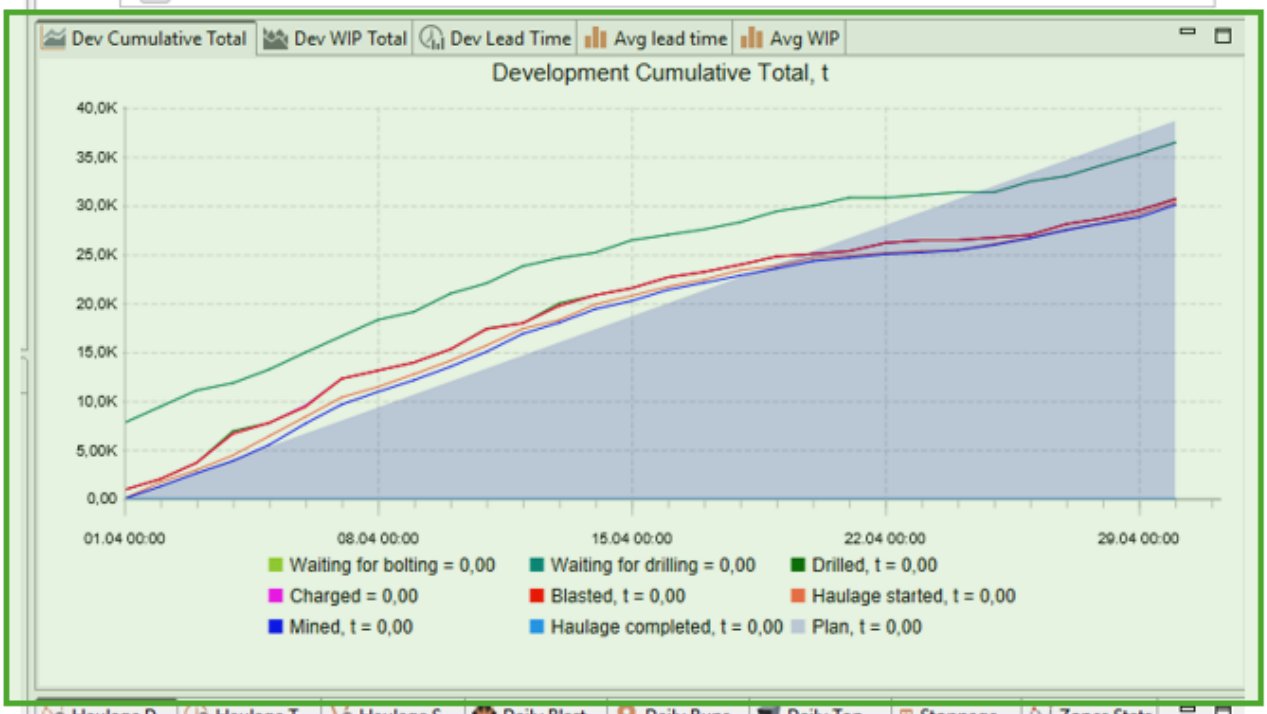
- **Ready for bolting, d** — time ore mass spends between becoming accessible and bolting start
- **Ready for drilling, d** — time ore mass spends between becoming bolted and drilling start
- **Drilled, d** — time ore mass spends between drilling and charging
- **Charged, d** — time between charging and blasting
- **Blasted, d** — time between blasting and the start of haulage
- **Haulage started, d** — time from haulage start to being considered as mined
- **Mined, d** — time from being considered as mined to being hauled to the final destination

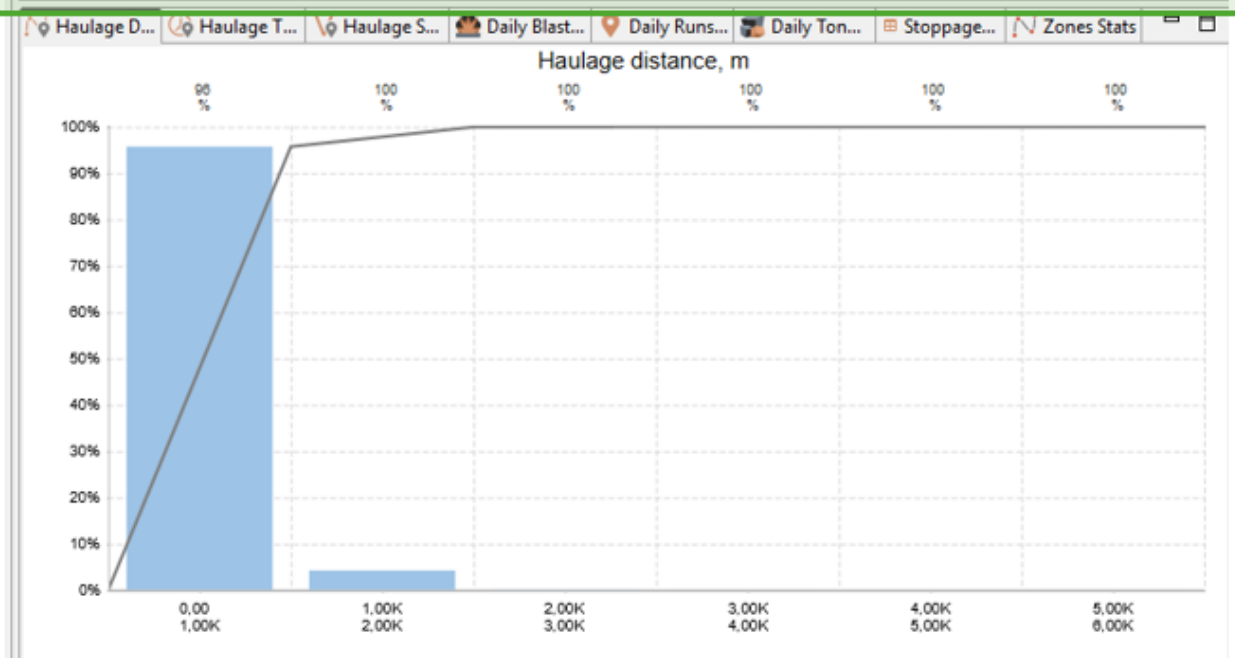
How to Use:

- Evaluate the total production cycle time: higher values indicate slower throughput.
- Identify stages that contribute most to delays — the thickest colored areas show where ore mass spends the most time.
- Track how lead time changes over the simulation period:
  - A growing slope means lead times are increasing (process is slowing down).
  - A declining or stable slope means throughput is improving or stable.
- Use this chart alongside the **WIP** and **Cumulative Total** charts to link time delays to ore mass accumulations.

2.4.7. Charts for analyzing development mining


Prod Cumulative Total
Prod Cumulative Substance
Prod WIP Total
Prod WIP Substance
Prod Lead Time
Production Cumulative Total, t
350K
300K
250K
200K
150K
100K
50,0K
0,00
01.04 00:00
08.04 00:00
15.04 00:00
22.04 00:00
Waiting for bolting
Waiting for drilling
Drilled, t
Charged
Blasted, t
Haulage started, t
Mined, t
Haulage completed, t
Plan, t


Dev Cumulative Total
Dev WIP Total
Dev Lead Time
Avg lead time
Avg WIP
Development Cumulative Total, t
40,0K
35,0K
30,0K
25,0K
20,0K
15,0K
10,0K
5,00K
0,00
01.04 00:00
08.04 00:00
15.04 00:00
22.04 00:00
29.04 00:00
Waiting for bolting = 0,00
Waiting for drilling = 0,00
Drilled, t = 0,00
Charged = 0,00
Blasted, t = 0,00
Haulage started, t = 0,00
Mined, t = 0,00
Haulage completed, t = 0,00
Plan, t = 0,00


Haulage D...
Haulage T...
Haulage S...
Daily Blast...
Daily Runs...
Daily Ton...
Stoppage...
Zones Stats
Haulage distance, m
96 %
100 %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0,00
1,00K
2,00K
3,00K
4,00K
5,00K
6,00K

In the middle right window there are 3 charts for development mining:

- Development cumulative total
- Development WIP total
- Development lead time

They have the same logic as corresponding charts for production mining.

Also, there are 2 bar graphs for averages:

- Average lead time
- Average WIP

2.4.8. Average lead time

This chart shows average lead time (in days) for different stages of the mining cycle, broken down into three categories: Summary, Production, and Development.

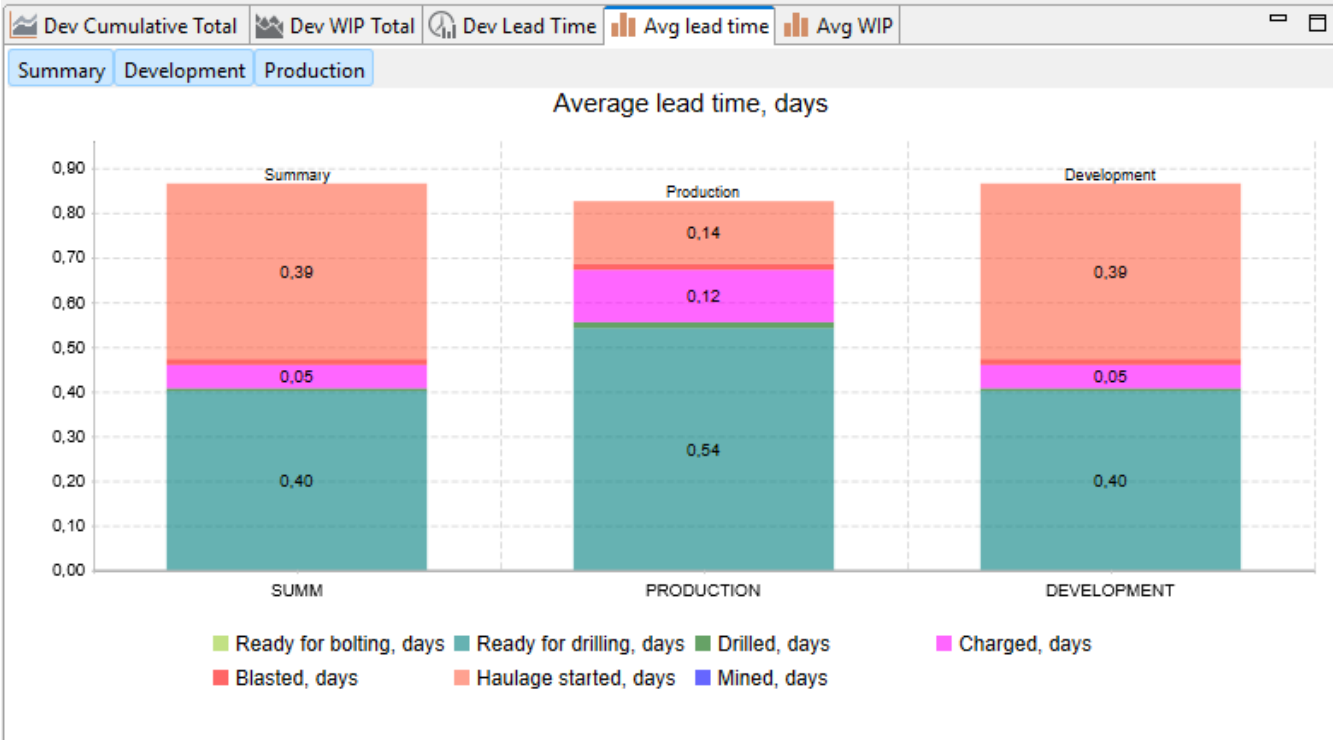


Chart Elements:

Each column is a stacked bar, where the total height represents the total average lead time, and each colored segment represents the duration of a specific stage:

- Ready for bolt installation, days
- Ready for drilling, days
- Drilled, days
- Charged, days
- Blasted, days

- Haulage started, days
- Mined, days

How to Use:

This visualization helps compare how different stages impact the total cycle duration and how production and development activities differ in their time structure.

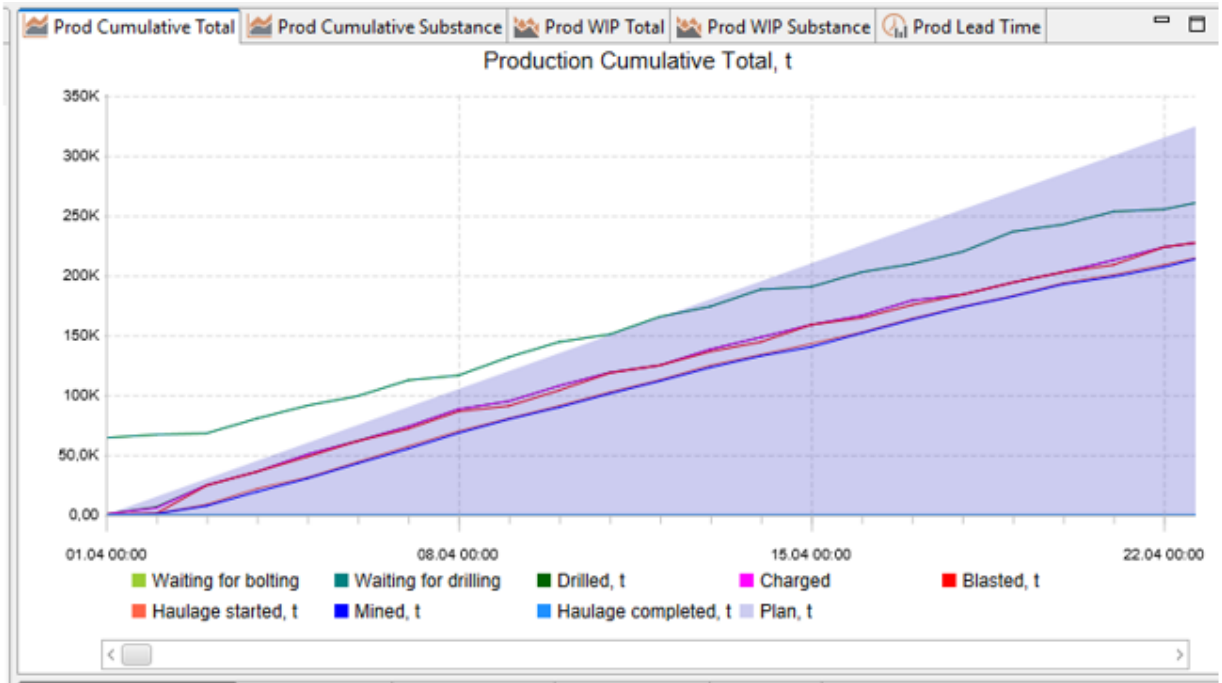
You can click buttons at the top of the graph to show/hide each stacked bar

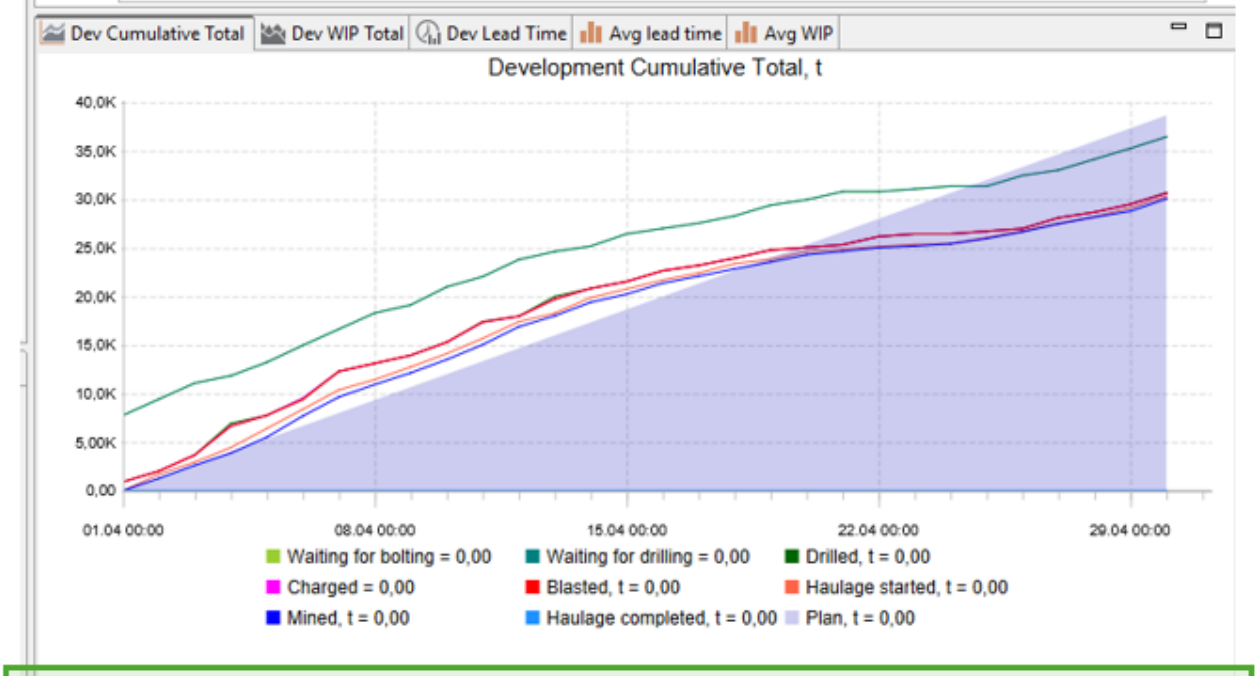
2.4.9. Average WIP

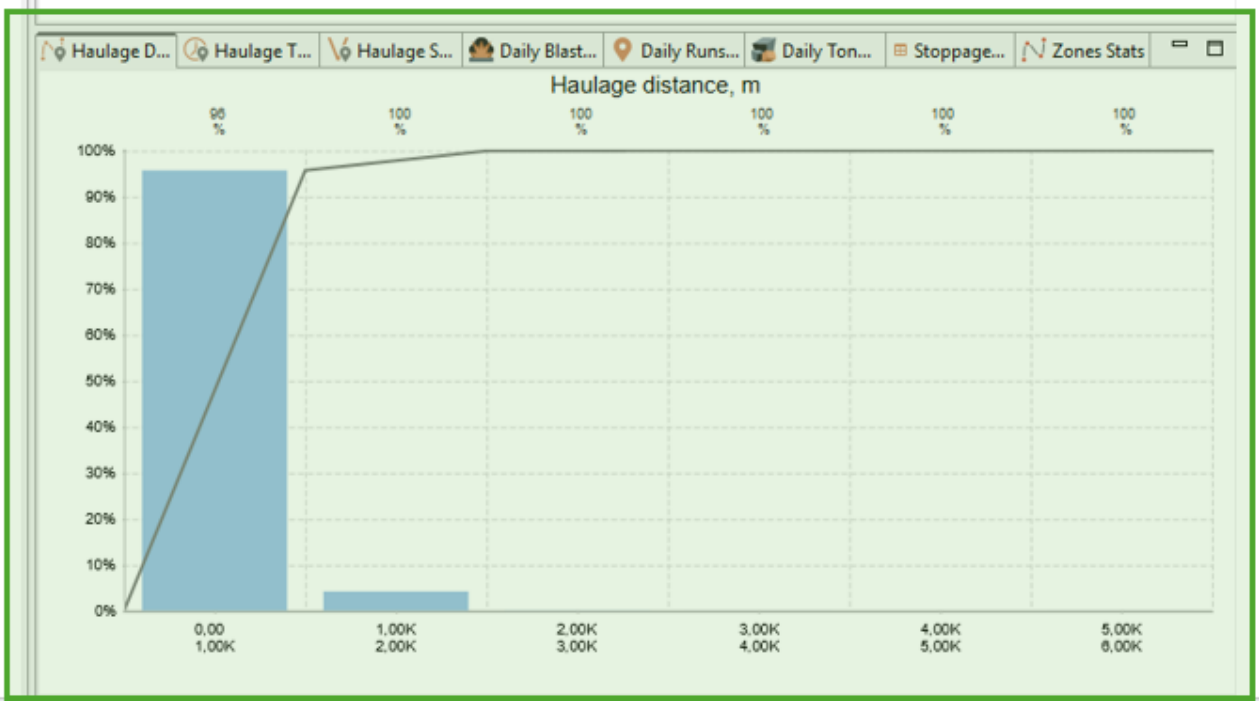
The **Average WIP** bar graph uses the same logic as **Average lead time** chart but for amount of WIP.

Note: On each chart you can click legend items to toggle the visibility of the corresponding data series. Clicking anywhere in the chart plot area will display the values of all visible data series at that point in time.

2.4.10. Other charts and tables


Prod Cumulative Total
Prod Cumulative Substance
Prod WIP Total
Prod WIP Substance
Prod Lead Time
Production Cumulative Total, t
350K
300K
250K
200K
150K
100K
50,0K
0,00
01.04 00:00
08.04 00:00
15.04 00:00
22.04 00:00
Waiting for bolting
Waiting for drilling
Drilled, t
Charged
Blasted, t
Haulage started, t
Mined, t
Haulage completed, t
Plan, t

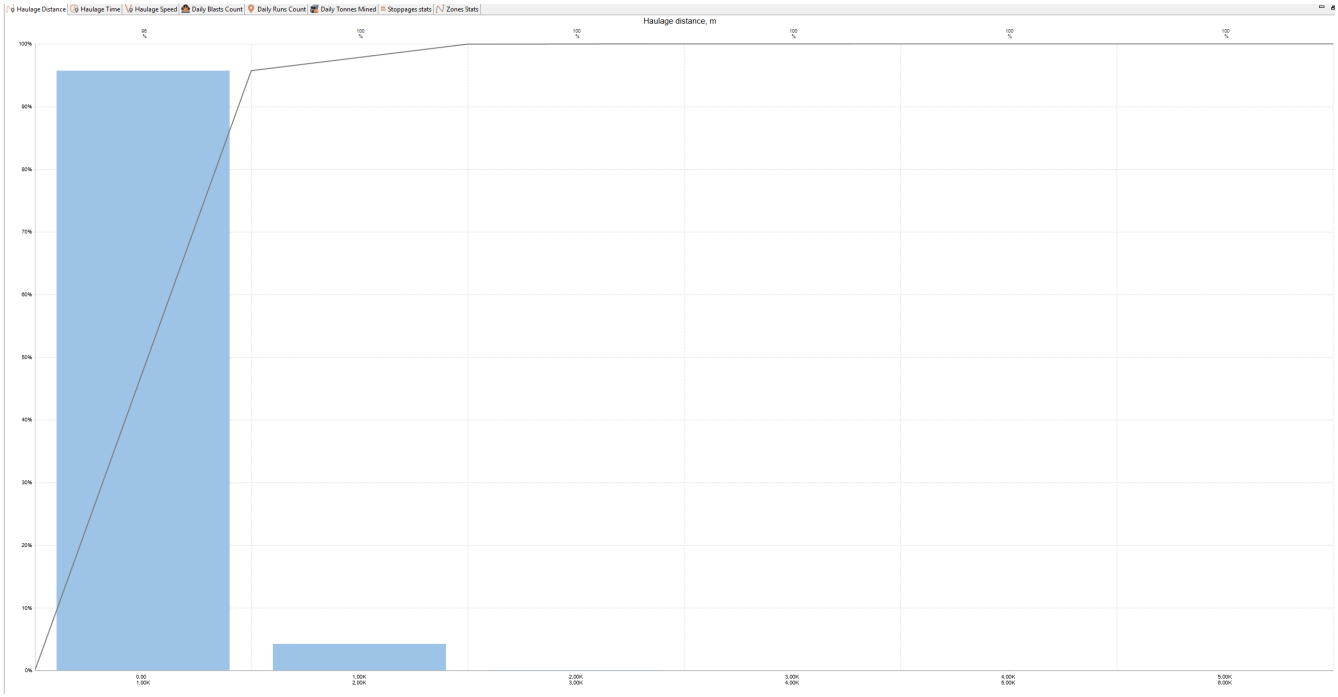

Dev Cumulative Total
Dev WIP Total
Dev Lead Time
Avg lead time
Avg WIP
Development Cumulative Total, t
40,0K
35,0K
30,0K
25,0K
20,0K
15,0K
10,0K
5,00K
0,00
01.04 00:00
08.04 00:00
15.04 00:00
22.04 00:00
29.04 00:00
Waiting for bolting = 0,00
Waiting for drilling = 0,00
Drilled, t = 0,00
Charged = 0,00
Blasted, t = 0,00
Haulage started, t = 0,00
Mined, t = 0,00
Haulage completed, t = 0,00
Plan, t = 0,00


Haulage D...
Haulage T...
Haulage S...
Daily Blast...
Daily Runs...
Daily Ton...
Stoppage...
Zones Stats
Haulage distance, m
96 %
100 %
100 %
100 %
100 %
100 %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0,00
1,00K
1,00K
2,00K
2,00K
3,00K
3,00K
4,00K
4,00K
5,00K
5,00K
6,00K

In the bottom-right window, several additional charts and tables are available, primarily focused on ore transportation statistics and other events.

2.4.11. Haulage Distance Chart

The **Haulage Distance** chart shows the distribution of haulage trip lengths (in meters) for all transportation runs completed during the simulation.



This chart helps analyze how far trucks or LHDs are traveling on average, identify typical haulage distances, and detect excessively long or inefficient routes that may reduce productivity.

Chart Elements:

- X-axis (horizontal): Haulage distance intervals (m)
- Y-axis (left vertical): Percentage of total trips in each distance interval
- Y-axis (right vertical, cumulative line): Cumulative percentage of all trips

Chart Components:

- **Blue bars** — show the share of trips within each distance interval (histogram)
- **Gray cumulative line** — shows the cumulative percentage of all trips as distance increases
- **Labels above bars** — show the exact cumulative percentage of all trips up to the current bin

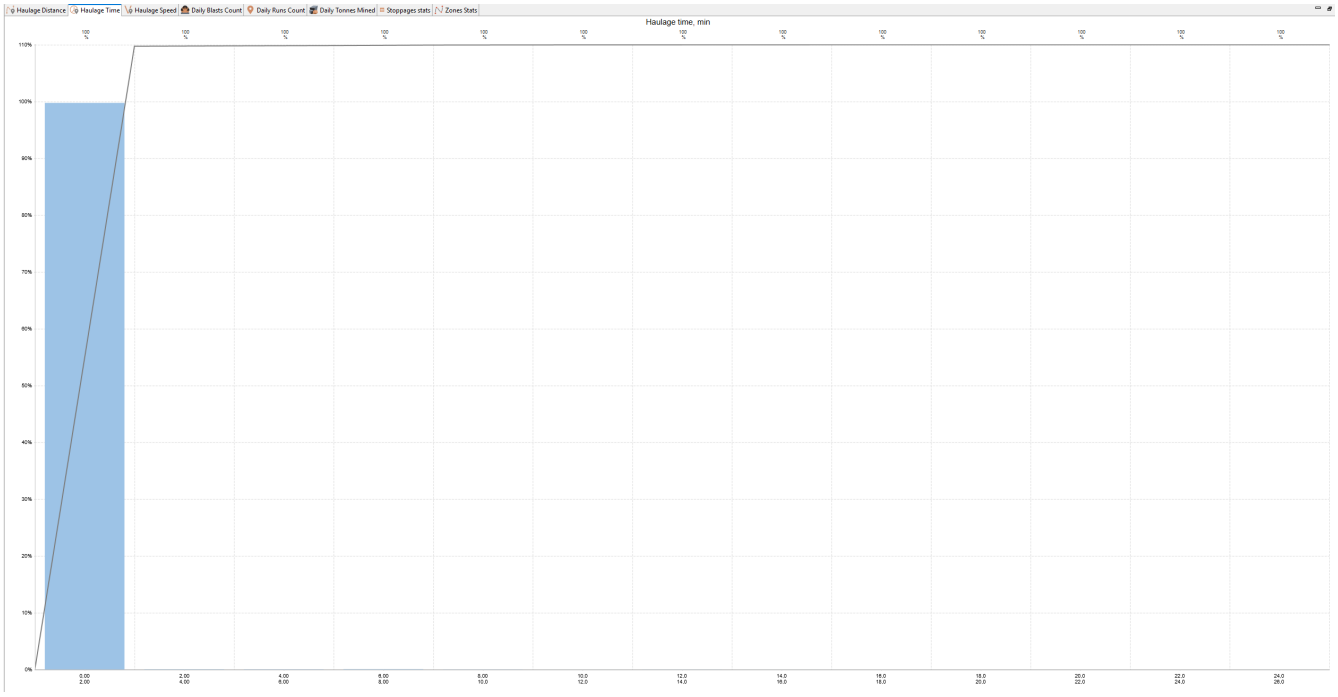
How to Use:

- Identify most common haulage distances — these appear as peaks in the histogram.
- Analyze distribution balance — if most trips are clustered at very short or very long distances, consider optimizing road layout or destination assignment.
- Track long-distance trips — high shares of long-distance hauling can indicate potential bottlenecks or inefficient routing.

- Use this chart together with **Haulage Time** and **Haulage Speed** charts to assess transport efficiency.

2.4.12. Haulage Time Chart

The **Haulage Time** chart shows the distribution of haulage trip durations (in minutes) for all transportation runs completed during the simulation.



This chart helps evaluate the efficiency of haulage operations by showing how long typical transportation cycles take. It helps identify unusually long or short trips, as well as detect delays that reduce fleet productivity.

Chart Elements:

- X-axis (horizontal): Haulage time intervals (minutes)
- Y-axis (left vertical): Percentage of total trips in each time interval
- Y-axis (right vertical, cumulative line): Cumulative percentage of all trips

Chart Components:

- **Blue bars** — show the share of trips within each time interval (histogram)
- **Gray cumulative line** — shows the cumulative percentage of all trips as time increases
- **Labels above bars** — show the exact cumulative percentage of all trips up to the current bin

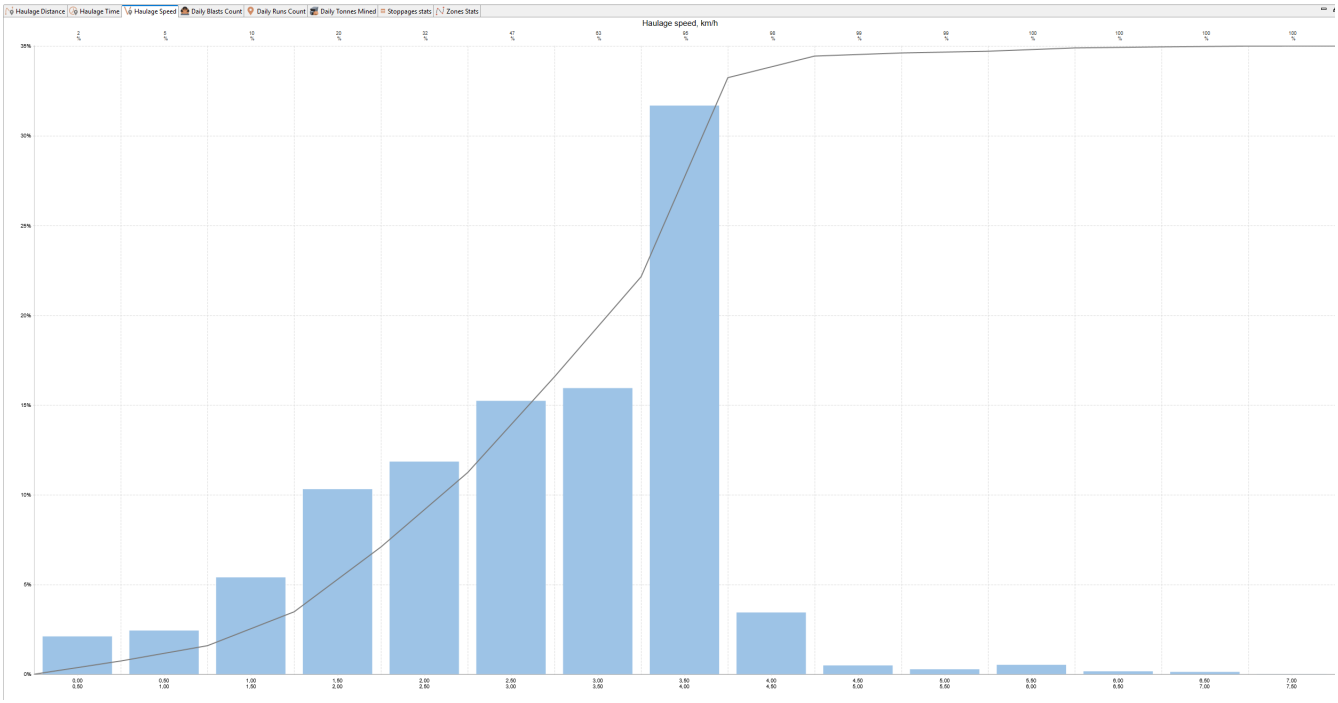
How to Use:

- Identify most common haulage times — these appear as peaks in the histogram.
- Detect abnormally long haulage times that may indicate delays, congestion, or breakdowns.
- Evaluate fleet performance stability — a tight distribution (narrow cluster of bars) indicates consistent operations, while a wide spread suggests unstable performance.

- Compare with the **Haulage Distance** and **Haulage Speed** charts to detect whether long times are due to longer routes or lower travel speeds.

2.4.13. Haulage Speed Chart

The **Haulage Speed** chart shows the distribution of average travel speeds (in kilometers per hour) achieved during all haulage trips completed in the simulation.



This chart helps evaluate the efficiency of haulage operations by showing how fast equipment moves on average, and it helps detect cases where low speeds may indicate congestion, steep gradients, poor road conditions, or mechanical issues.

Chart Elements:

- X-axis (horizontal): Haulage speed intervals (km/h)
- Y-axis (left vertical): Percentage of total trips in each speed interval
- Y-axis (right vertical, cumulative line): Cumulative percentage of all trips

Chart Components:

- **Blue bars** — show the share of trips within each average speed range (histogram)
- **Gray cumulative line** — shows the cumulative percentage of all trips as speed increases
- **Labels above bars** — show the exact cumulative percentage of all trips up to the current bin

How to Use:

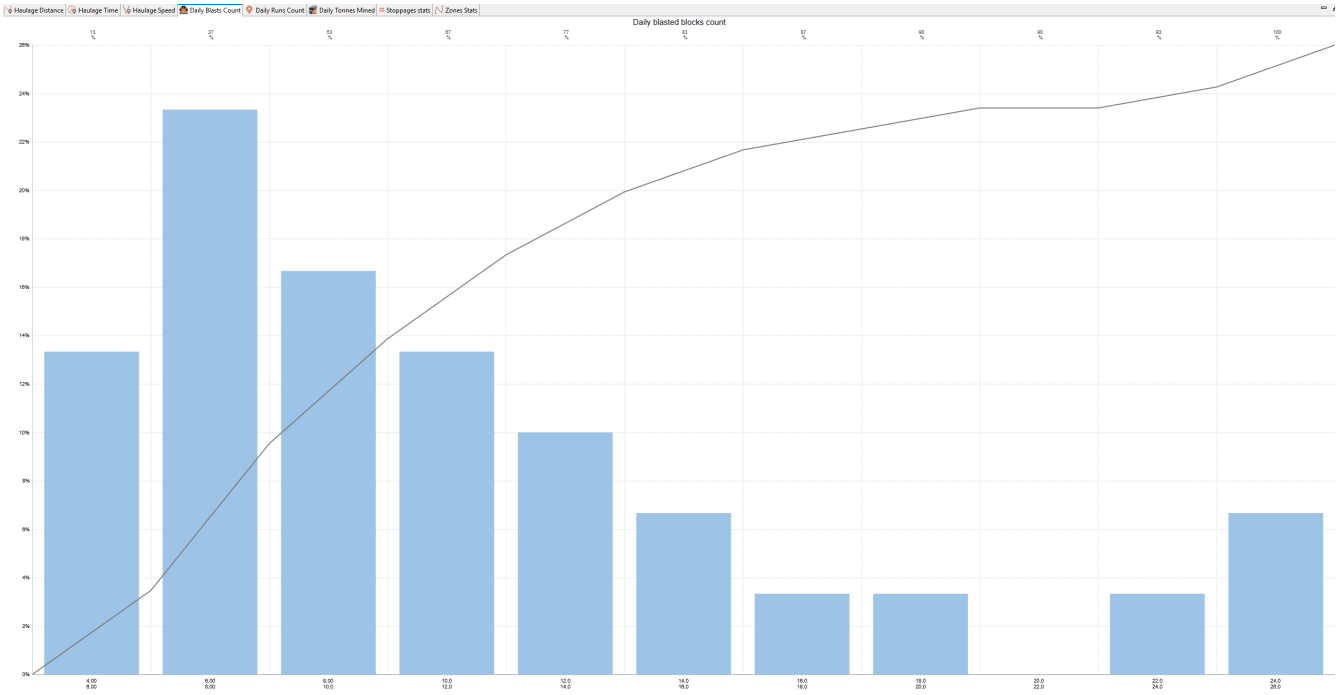
- Identify most common travel speeds — these appear as peaks in the histogram.
- Detect low average speeds, which may indicate poor road conditions, queues or delays caused by traffic congestion.
- Evaluate speed consistency — a narrow cluster of speeds means stable performance, while a

wide spread indicates variation between trips.

- Use together with **Haulage Time** and **Haulage Distance** charts to understand whether long travel times are caused by longer distances or lower speeds.

2.4.14. Daily Blasts Count Chart

The **Daily Blasted Blocks Count** chart shows the distribution of the number of blocks blasted per day during the simulation period.



This chart helps evaluate the intensity and regularity of blasting operations. It indicates how often blasting events occur and whether they are concentrated in large batches or evenly spread out over time.

Chart Elements:

- X-axis (horizontal): Number of blasted blocks per day
- Y-axis (left vertical): Percentage of simulation days that had this number of blasted blocks
- Y-axis (right vertical, cumulative line): Cumulative percentage of all days that had this number of blasts or fewer

Chart Components:

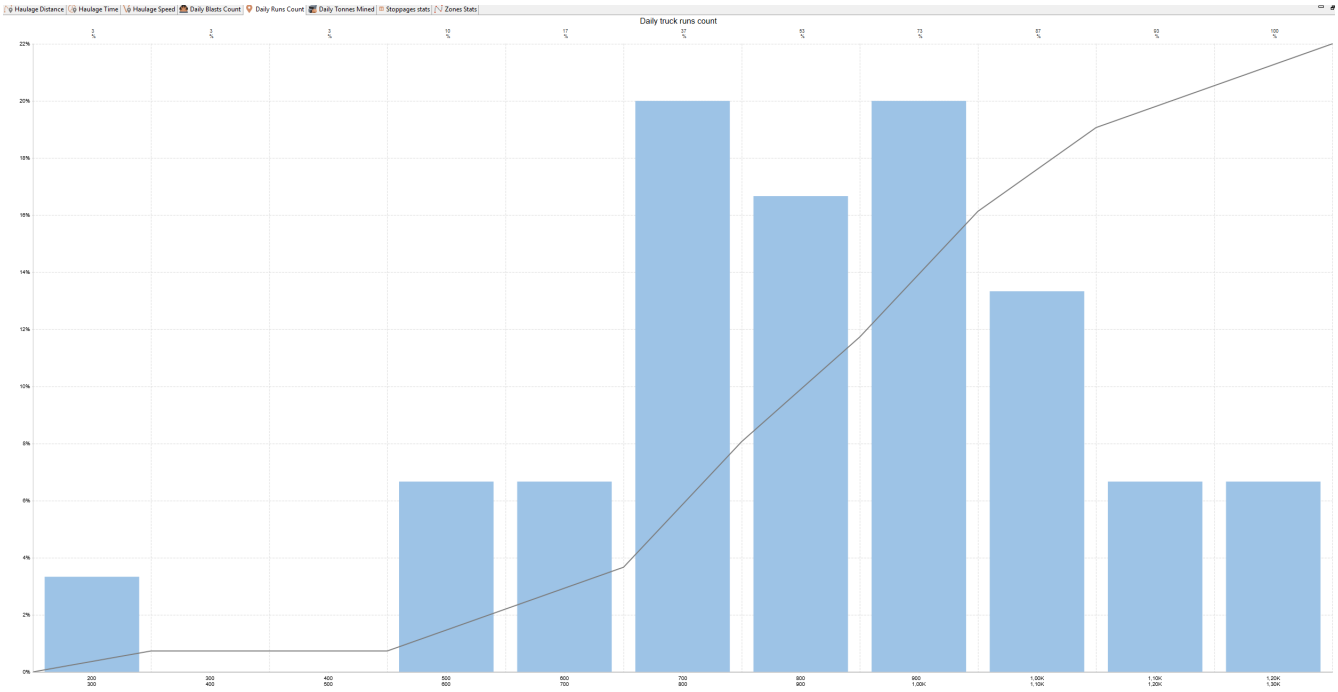
- **Blue bars** — show the share of days that had the specified number of blasted blocks
- **Gray cumulative line** — shows the cumulative percentage of all days that had this or fewer number of blasts
- **Labels above bars** — show the exact cumulative percentage of all days that had this or fewer number of blasts

How to Use:

- Identify typical blasting frequency — shown by the highest bar.
- Detect bursty vs. steady blasting:
  - A single tall bar near zero means blasting happens infrequently.
  - A wider spread of bars means more consistent daily blasting.
- Use this chart alongside **Daily Runs Count** and **Daily Tonnes Mined** charts to see how blasting activity influences production cycles.

2.4.15. Daily Runs Count Chart

The **Daily Runs Count** chart shows the distribution of the number of loaded haulage runs (trips with ore or waste) completed per day during the simulation period.



This chart helps analyze the intensity and consistency of haulage operations. It shows how many loaded trips are typically performed in a day and highlights whether hauling activity is steady or highly variable.

Chart Elements:

- X-axis (horizontal): Number of loaded runs per day
- Y-axis (left vertical): Percentage of simulation days that had this number of loaded runs
- Y-axis (right vertical, cumulative line): Cumulative percentage of all days that had this number of runs or fewer

Chart Components:

- **Blue bars** — show the share of days that had the specified number of loaded runs
- **Gray cumulative line** — shows the cumulative percentage of all days that had this or fewer number runs
- **Labels above bars** — show the exact cumulative percentage of days that had this or fewer

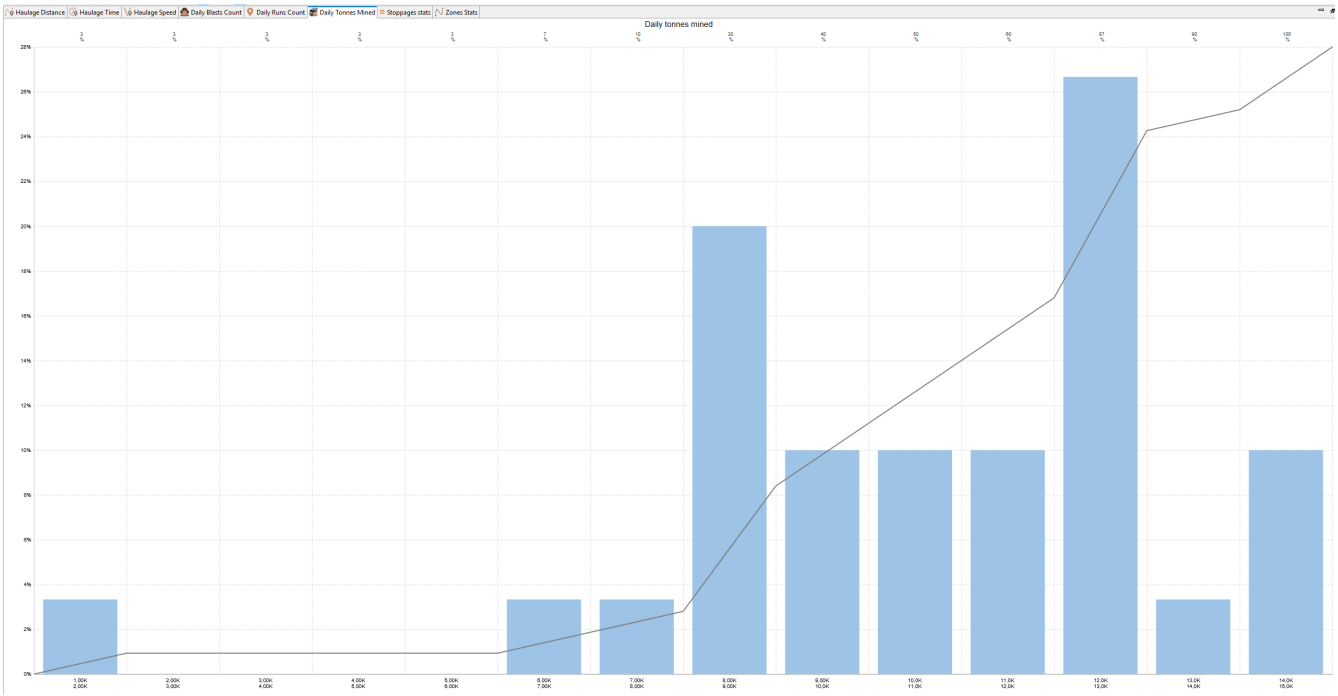
number runs

How to Use:

- Identify the most common daily workload for haul trucks or LHDs (the tallest bar).
- Detect uneven hauling performance — a wide spread of bars indicates large fluctuations in daily output.
- Spot low-activity days — tall bars near zero show days with little or no hauling.
- Use this chart alongside the **Daily Blasted Blocks Count** and **Daily Tonnes Mined** charts to see how hauling activity aligns with blasting and production cycles.

2.4.16. Daily Tonnes Mined Chart

The **Daily Tonnes Mined** chart shows the distribution of the total amount of ore mass (in tonnes) considered as mined per day during the simulation period.



This chart helps evaluate the daily production performance of the mining operation. It shows how much ore mass is typically considered as mined in a day and whether production rates are stable or vary significantly between days.

Chart Elements:

- X-axis (horizontal): Total mined tonnage per day
- Y-axis (left vertical): Percentage of simulation days that had this amount of mined material
- Y-axis (right vertical, cumulative line): Cumulative percentage of all days that had this amount or less

Chart Components:

- **Blue bars** — show the share of days that had the specified daily mined tonnage

- **Gray cumulative line** — shows the cumulative percentage of all days as the mined tonnage increases
- **Labels above bars** — show the exact cumulative percentage of days up to the current bin

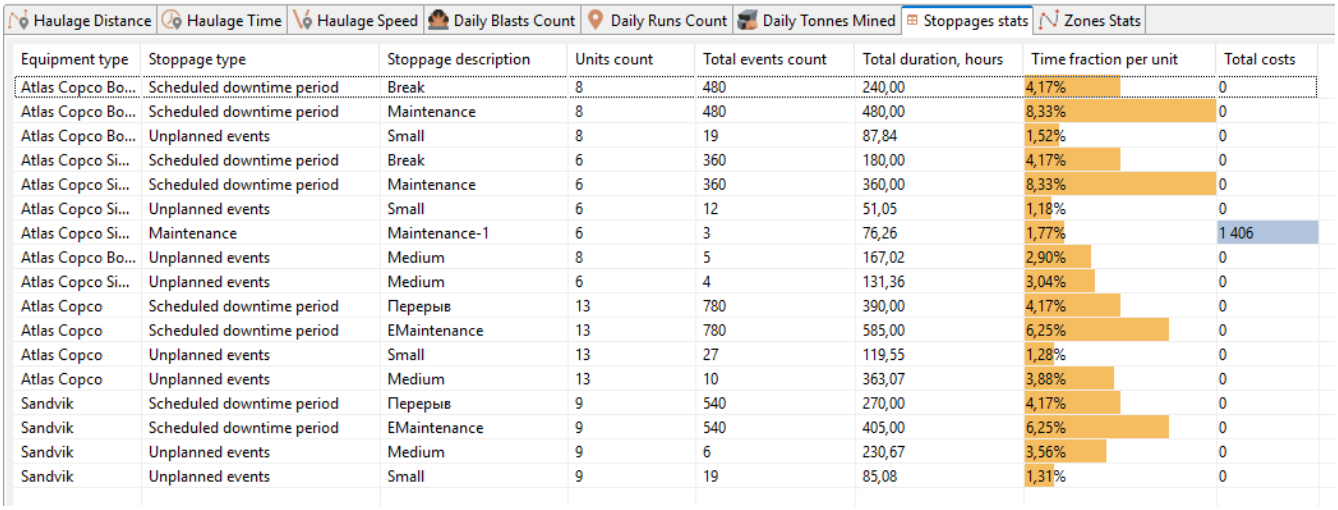
How to Use:

- Identify the typical daily production output — the tallest bar shows the most common production level.
- Detect low-production days — tall bars near zero may indicate downtime or operational disruptions.
- Check consistency of output — a narrow cluster of bars shows stable production; a wide spread indicates fluctuating performance.
- Use this chart alongside **Daily Runs Count** and **Daily Blasted Blocks Count** charts to understand how production aligns with hauling and blasting activity.

Note: In all histograms, the left boundary of each range is inclusive, while the right boundary is exclusive. This means that, for example, in the 0–1 range (with an integer number of blasts), only days with 0 blasts will be included.

2.4.17. Stoppage Stats Table

The **Stoppage Stats** table summarizes all downtime events that occurred during the simulation, grouped by equipment type and stoppage typen. It provides an overview of how much time equipment spent unavailable due to scheduled or unplanned stoppages.



Haulage Distance | Haulage Time | Haulage Speed | Daily Blasts Count | Daily Runs Count | Daily Tonnes Mined | Stoppages stats | Zones Stats

Equipment type	Stoppage type	Stoppage description	Units count	Total events count	Total duration, hours	Time fraction per unit	Total costs
Atlas Copco Bo...	Scheduled downtime period	Break	8	480	240,00	4,17%	0
Atlas Copco Bo...	Scheduled downtime period	Maintenance	8	480	480,00	8,33%	0
Atlas Copco Bo...	Unplanned events	Small	8	19	87,84	1,52%	0
Atlas Copco Si...	Scheduled downtime period	Break	6	360	180,00	4,17%	0
Atlas Copco Si...	Scheduled downtime period	Maintenance	6	360	360,00	8,33%	0
Atlas Copco Si...	Unplanned events	Small	6	12	51,05	1,18%	0
Atlas Copco Si...	Maintenance	Maintenance-1	6	3	76,26	1,77%	1 406
Atlas Copco Bo...	Unplanned events	Medium	8	5	167,02	2,90%	0
Atlas Copco Si...	Unplanned events	Medium	6	4	131,36	3,04%	0
Atlas Copco	Scheduled downtime period	Перерыв	13	780	390,00	4,17%	0
Atlas Copco	Scheduled downtime period	EMaintenance	13	780	585,00	6,25%	0
Atlas Copco	Unplanned events	Small	13	27	119,55	1,28%	0
Atlas Copco	Unplanned events	Medium	13	10	363,07	3,88%	0
Sandvik	Scheduled downtime period	Перерыв	9	540	270,00	4,17%	0
Sandvik	Scheduled downtime period	EMaintenance	9	540	405,00	6,25%	0
Sandvik	Unplanned events	Medium	9	6	230,67	3,56%	0
Sandvik	Unplanned events	Small	9	19	85,08	1,31%	0

This table helps analyze the impact of various downtime reasons (such as weather, maintenance, or blasting) on equipment availability and productivity.

Table Columns:

- **Equipment type** — the type or model of equipment affected by the stoppages
- **Stoppage type** — the category of downtime
- **Stoppage description** — the specific name of the stoppage (for example, Blast 1 or Meteo)
- **Units count** — the number of equipment units of this type that experienced this stoppage

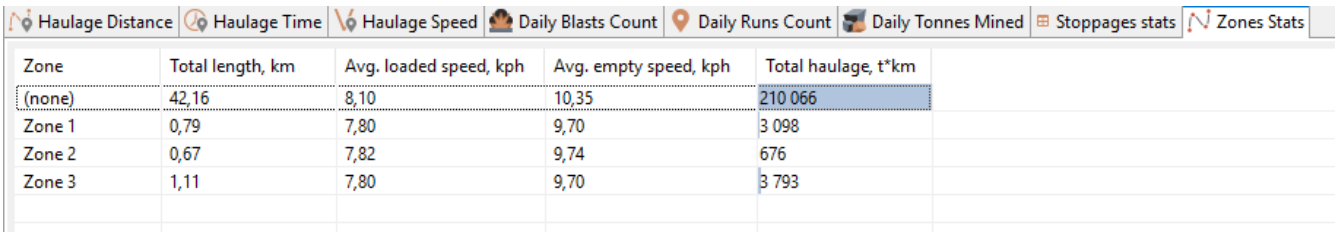
- **Total events count** — the total number of stoppage events of this type that occurred during the simulation
- **Total duration, hours** — total time (in hours) that equipment was unavailable due to this stoppage
- **Time fraction per unit** — share of total scheduled operational time that each affected unit spent in this stoppage state (shown as a percentage)
- **Total costs** — total costs associated with this stoppage (if cost parameters are configured)

How to Use:

- Identify which types of stoppages cause the largest downtime (look at Total duration, hours and Time fraction per unit).
- Distinguish between planned and unplanned stoppages to assess operational reliability.
- Use this data to refine schedules (e.g., plan maintenance better or reduce weather exposure) and improve equipment availability.
- If cost tracking is enabled, compare downtime-related costs across equipment types.

2.4.18. Zone Stats Table

The **Zone Stats** table provides a breakdown of transportation performance indicators by zone. Zones are user-defined areas of the haulage network, used to group road segments (arcs) for analysis.



Zone	Total length, km	Avg. loaded speed, kph	Avg. empty speed, kph	Total haulage, t*km
(none)	42,16	8,10	10,35	210 066
Zone 1	0,79	7,80	9,70	3 098
Zone 2	0,67	7,82	9,74	676
Zone 3	1,11	7,80	9,70	3 793

This table helps evaluate the efficiency of haulage operations within different parts of the mine by comparing travel distances, speeds, and transported volumes across zones.

Table Columns:

- **Zone** — the name of the zone assigned to road segments (or (none) if not assigned)
- **Total length, km** — the total combined length of all segments within this zone
- **Avg. loaded speed, kph** — the average speed of equipment moving with a load inside this zone
- **Avg. empty speed, kph** — the average speed of equipment moving without a load inside this zone
- **Total haulage, t*km** — the total haulage work performed in this zone, measured as **tonnes transported × kilometers traveled**

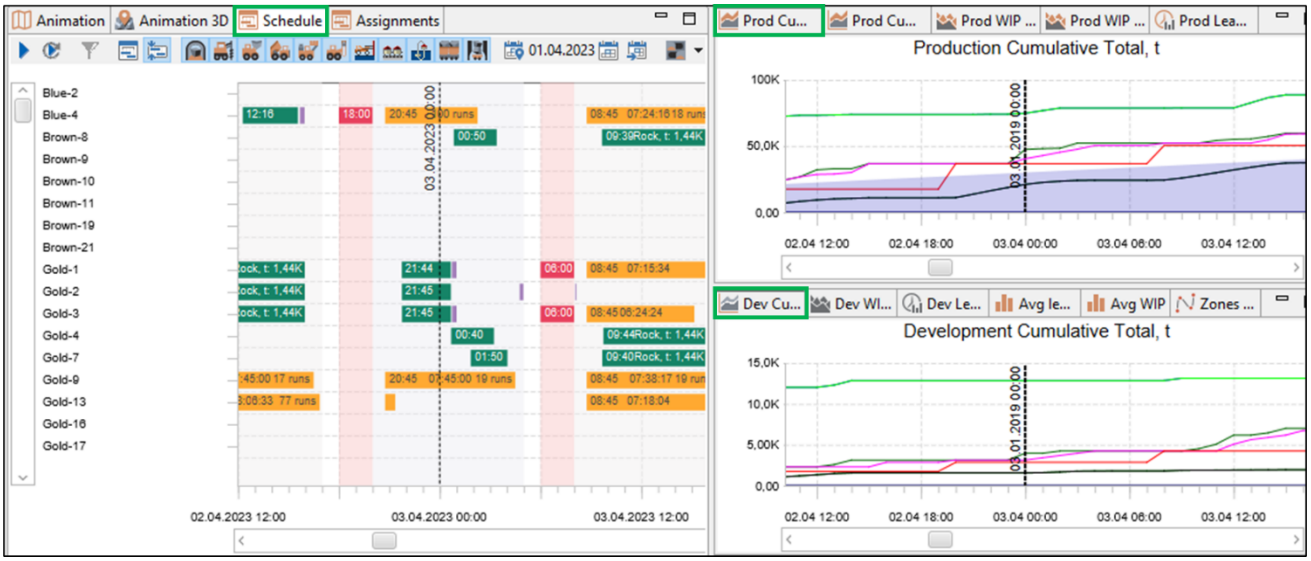
How to Use:

- Identify zones with high haulage workload — large values in **Total haulage, t*km** indicate

areas where most transport effort is concentrated.

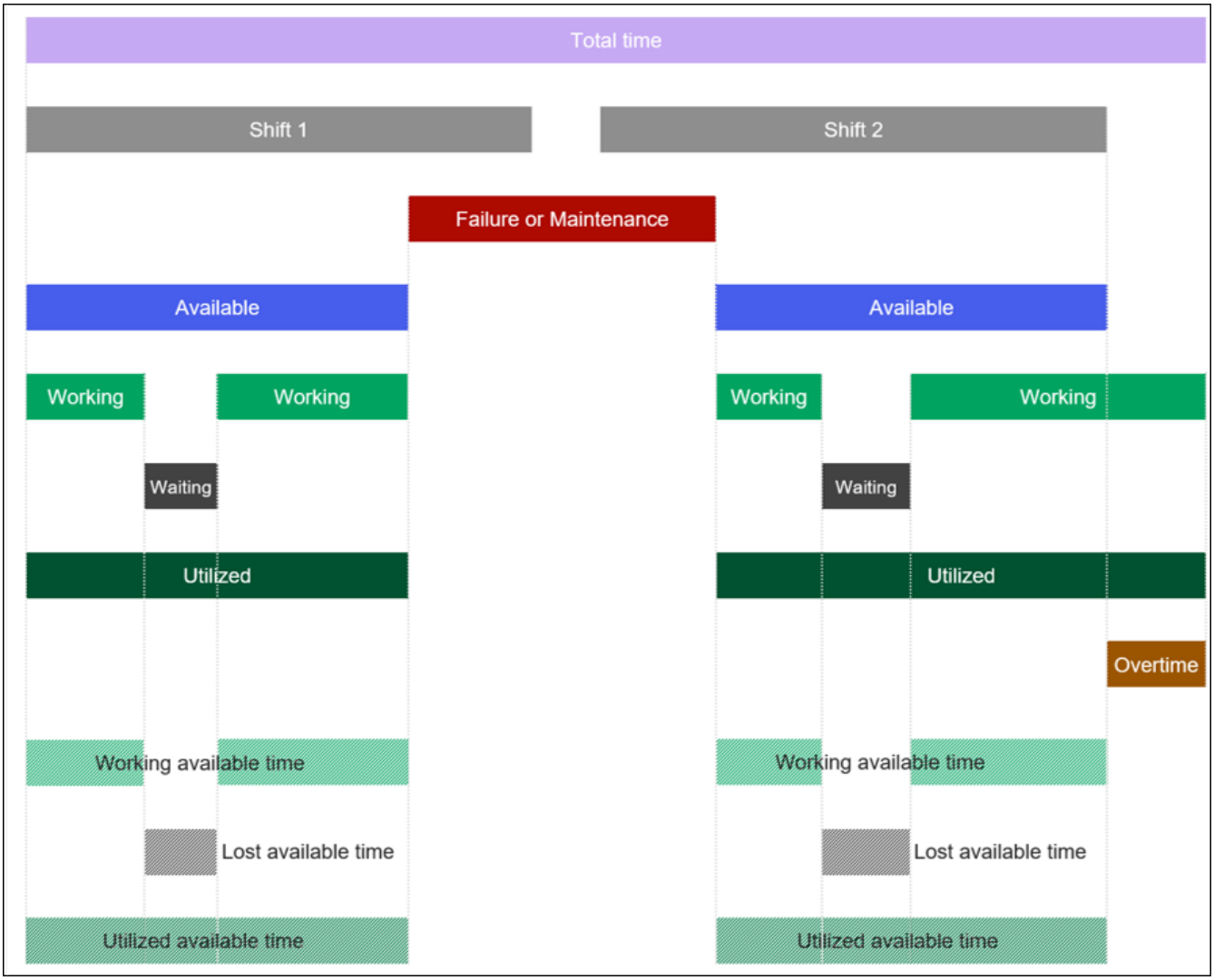
- Analyze travel speed differences between zones to detect possible bottlenecks (low speeds may signal steep gradients, congestion, or poor road conditions).
- Evaluate zone coverage — check **Total length** to see which areas dominate the road network.
- Use this data to optimize traffic organization and road maintenance priorities.

By pressing the button  in the top toolbar, cumulative graphs are synchronized with the schedule.



2.5. Availability and utilization calculation

Understanding equipment availability and utilization is crucial for optimizing mining operations and minimizing downtime. MineTwin's simulation tool provides a clear framework to track key metrics like total time, scheduled time, and utilized time, helping identify inefficiencies and improve equipment performance. These insights support better understanding of simulation results.

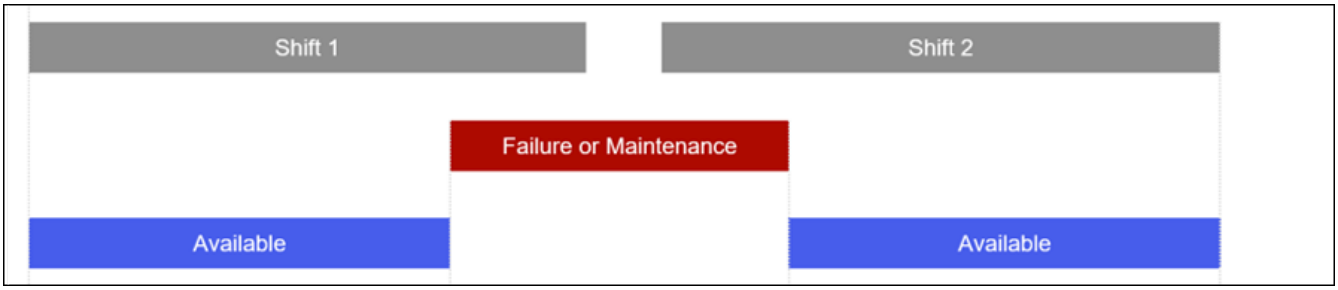


On the scheme above, there are the following categories of time periods and time usage:

Total time – total time since the beginning of the simulation.

Scheduled time – time there was a shift scheduled for the equipment. For equipment without shifts, scheduled time = total simulation time or total time between commissioning and decommissioning, if these are specified for this equipment.

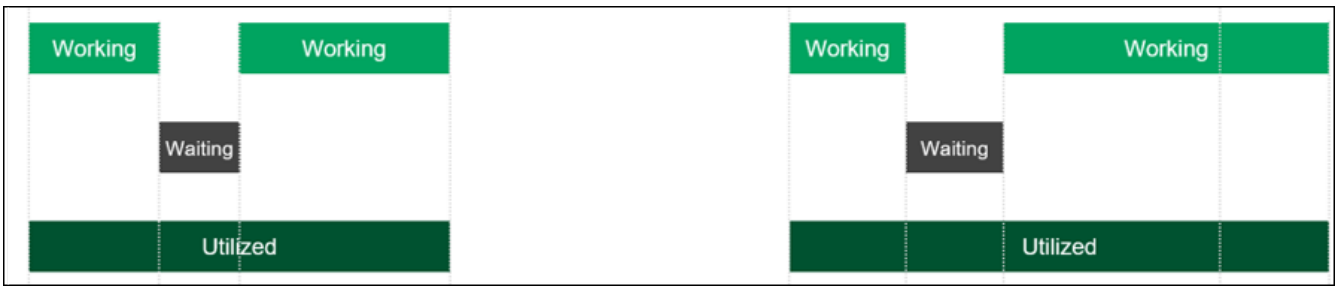
Unavailable time – duration of slots classified as UNAVAILABLE. Typically, failures and maintenances fall into this category.



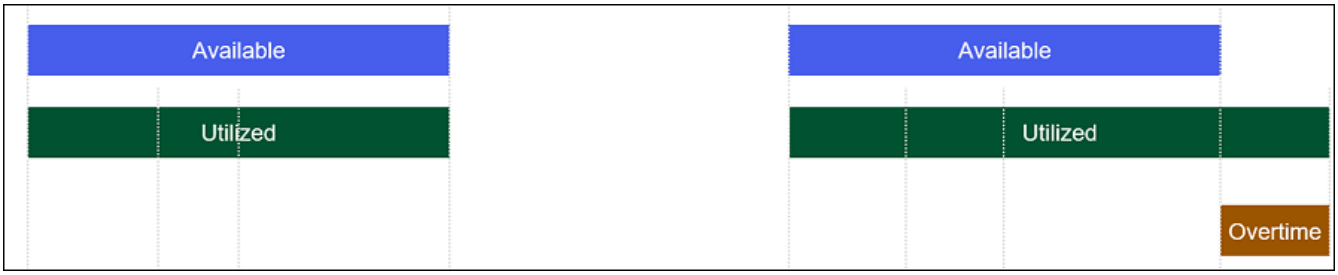
Available time is calculated as scheduled time excluding unavailable time.

Working time – duration of slots classified as ACTUAL_WORKING, doing actual useful work. For example, for trucks it would include moving to loading location, loading, moving loaded to unloading location, and unloading

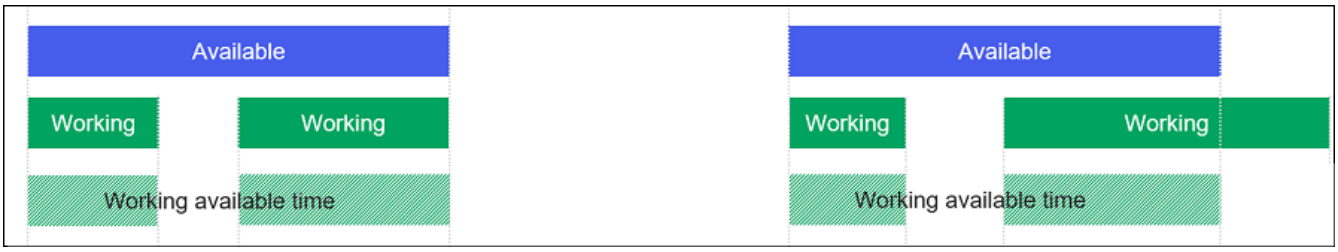
Lost time (also can be called **Waiting time**) – duration of slots classified as LOST_TIME, waiting for something or being blocked. For example, for trucks it would include waiting in front of an unloading point or queuing in front of an loader.



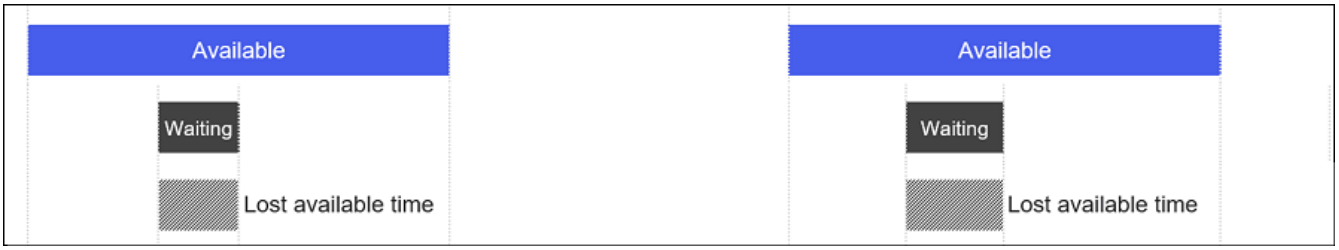
Utilized time is calculated as working time united with lost time.



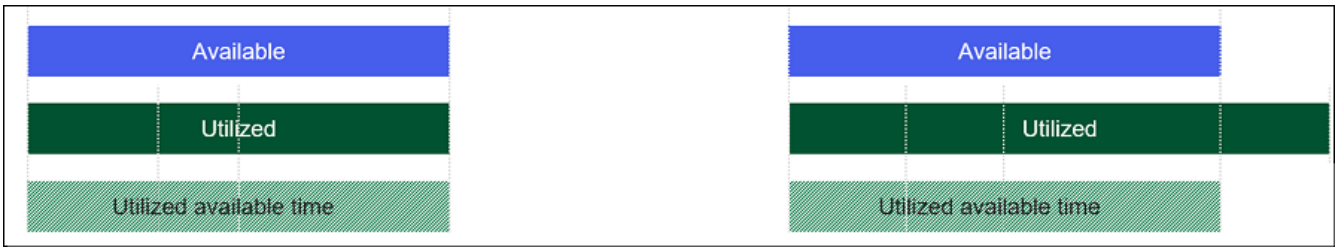
Overtime is calculated as utilized time excluding available time, should be negligibly small in real scenarios.



Working available time is calculated as working time intersected with available time.



Lost available time is calculated as lost time intersected with available time.



Utilized available time is calculated as utilized time intersected with available time.

The above time usage categories are used to calculate availability, utilization, effective utilization, and lost time fraction for individual equipment units and groups:

Availability is calculated as a fraction of scheduled time when the equipment was available:

$$\textbf{Availability} = \frac{Available\ time}{Scheduled\ time}$$

Utilization is calculated as a fraction of available time when the equipment was utilized (e.g. either working or actively waiting for something):

$$\textbf{Utilization} = \frac{Utilized\ available\ time}{Available\ time}$$

Effective utilization is calculated as a fraction of available time when the equipment was working (i.e., doing the useful work):

$$\textbf{Effective utilization} = \frac{Working\ available\ time}{Available\ time}$$

Lost time fraction is calculated as a fraction of utilized available time when the equipment was

actively waiting for something or was otherwise blocked:

$$\textbf{Lost time fraction} = \frac{Lost\ available\ time}{Utilized\ available\ time}$$

3. MineTwin Study Mode

3.1. Introduction

The **Study** mode is designed for conducting structured simulation experiments based on MineTwin scenarios. It allows users to analyze constraints, select an appropriate fleet configuration, and assess how sensitive results are to changes in model parameters.

This mode helps answer questions such as:

- which constraint has the strongest impact on achieving the plan;
- which fleet composition change would bring the result closer to the target plan;
- how results would change if the amount of equipment changes;
- which factors have the greatest influence on the final KPIs.

A study is created based on an open scenario. After creation, you can add steps, run automated study modes, execute calculations locally or on the server, compare results, and generate reports.

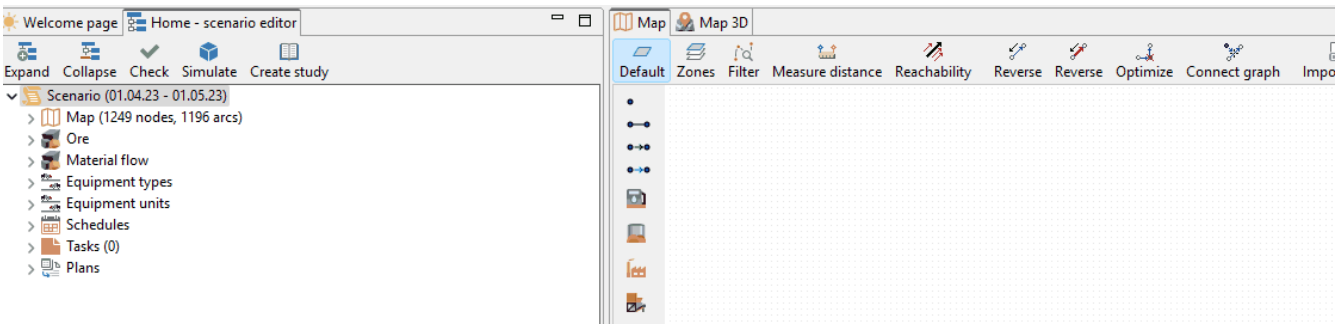
This structured approach improves analytical efficiency by making it easier to formulate and test hypotheses and quickly obtain well-grounded, reliable answers.

3.2. Creating a New Study

1. Open the required scenario.
2. Click **Create Study** on the toolbar.
3. The study opens in a new tab.
4. The current scenario becomes the study's **root step**. Child steps can be added to it.

The following commands are available for managing a study:

- **Rename** — a dedicated button on the study toolbar;
- **Save** and **Save As** — save the study as a ZIP archive;
- **Open Experiment** — open a previously saved study from the top menu in the **Menu** group.



3.3. Steps and Modifications

A study is built as a tree of steps. The base step contains the original scenario with no changes. Subsequent steps can:

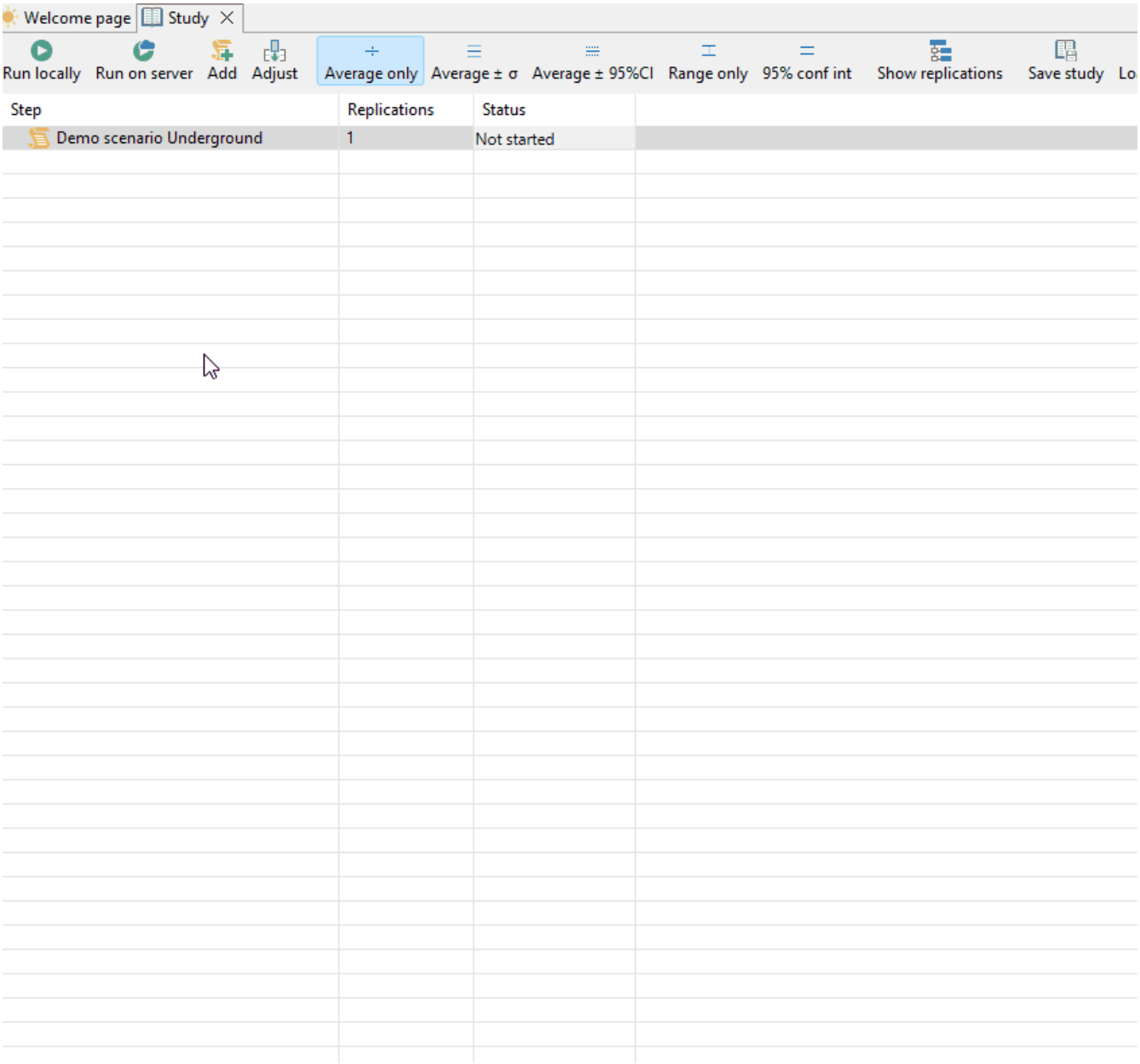
- inherit the scenario from the previous step and contain one or more modifications;
- be executed with multiple replications;
- be used as a basis for further experiments.

The user can:

- apply a modification to any study step;
- run an automated study for any step;
- create a new study from an intermediate step via right-click and the context menu;
- save any step as a separate scenario via right-click and the scenario save command;

3.3.1. Adding Modifications Manually

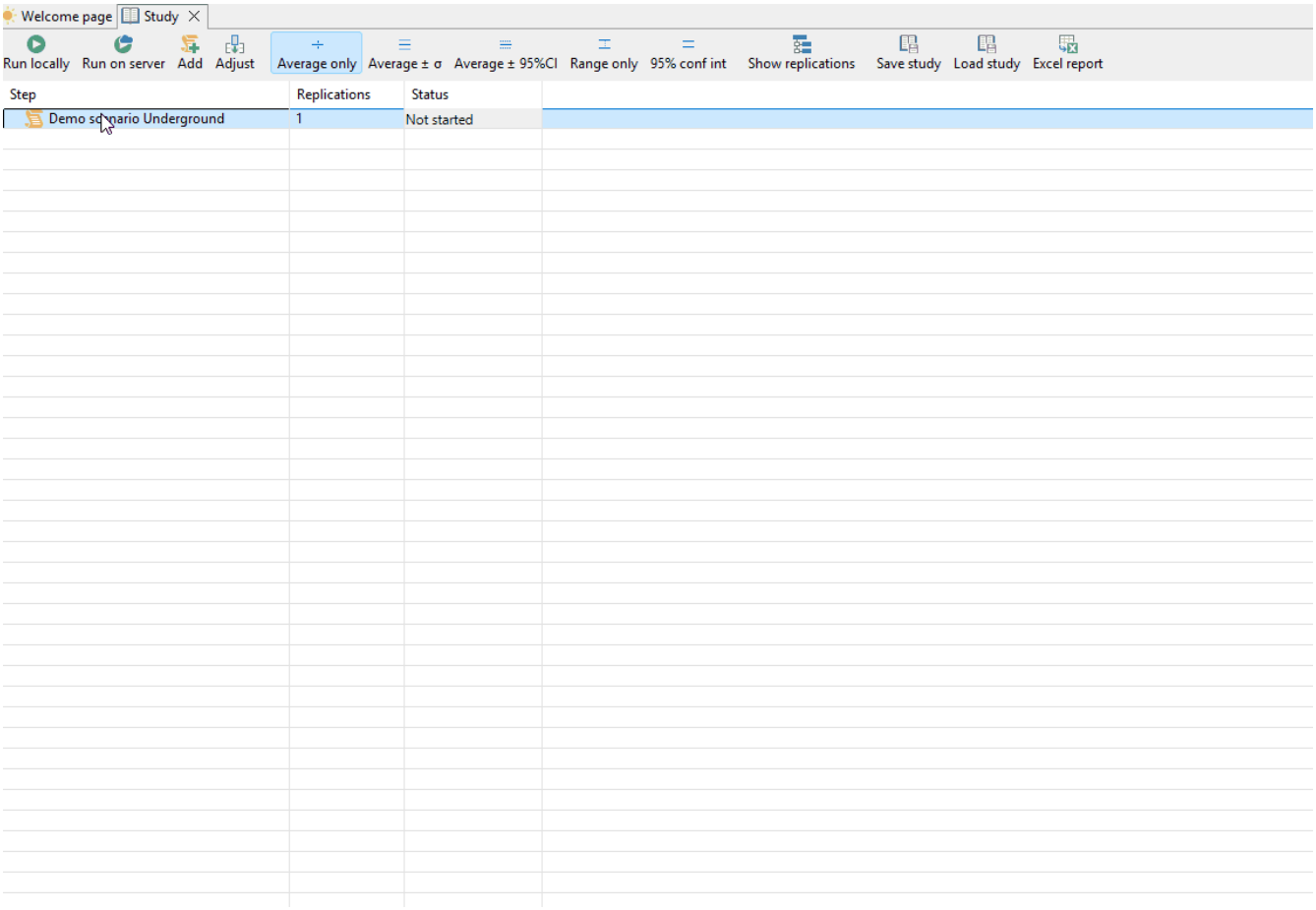
1. Select an existing step.
2. Right-click the step and select **"XX modifications available"** from the context menu. The total number of available modifications depends on the MineTwin version.



Modifications include:

- Removing maintenance downtime
- Removing equipment assignment to mining areas
- Doubling the number of trucks, loaders, drills and chargers
- Allowing passage of unmined stopes
- Duplicating the target plan etc.

Any intermediate step can be used as the root step of a new study. This makes it possible to branch the analysis at the required moment and compare alternative scenarios.



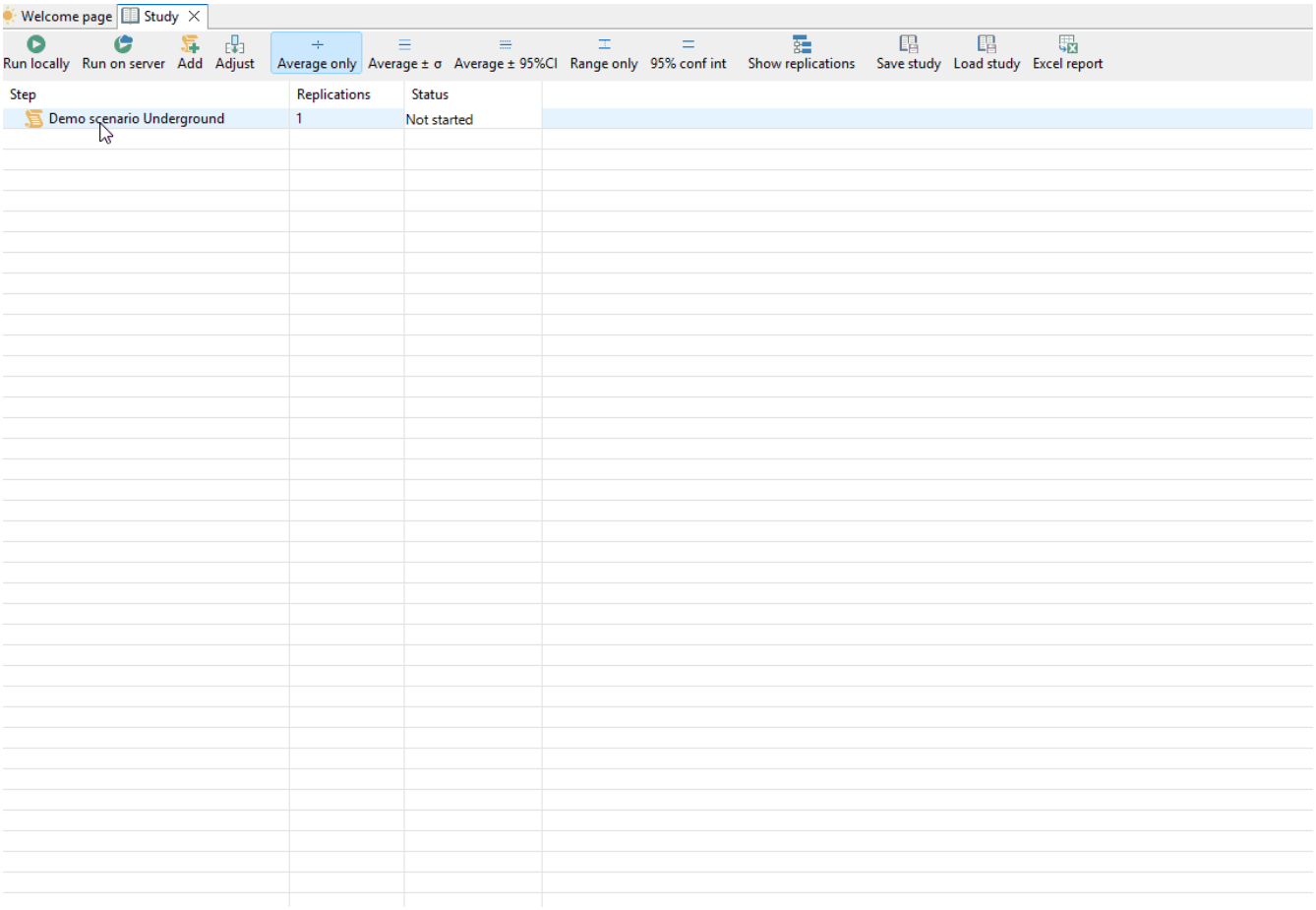
3.3.2. Automated Study Modes

Instead of adding individual modifications, you can run one of the automated study modes.

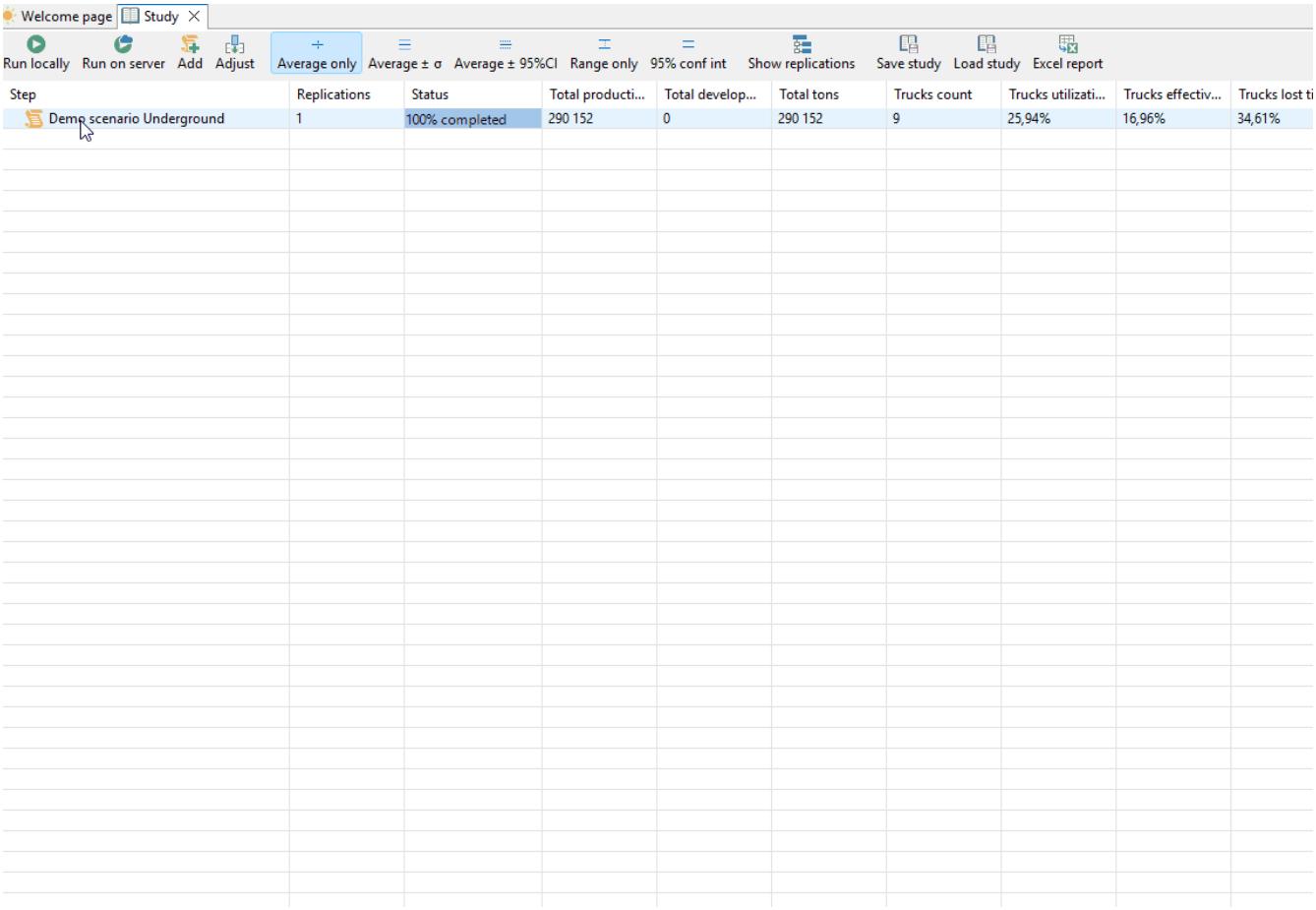
The following automated studies are available:

- Constraint Analysis
- Fleet Sizing
- Equipment Units Count Variation

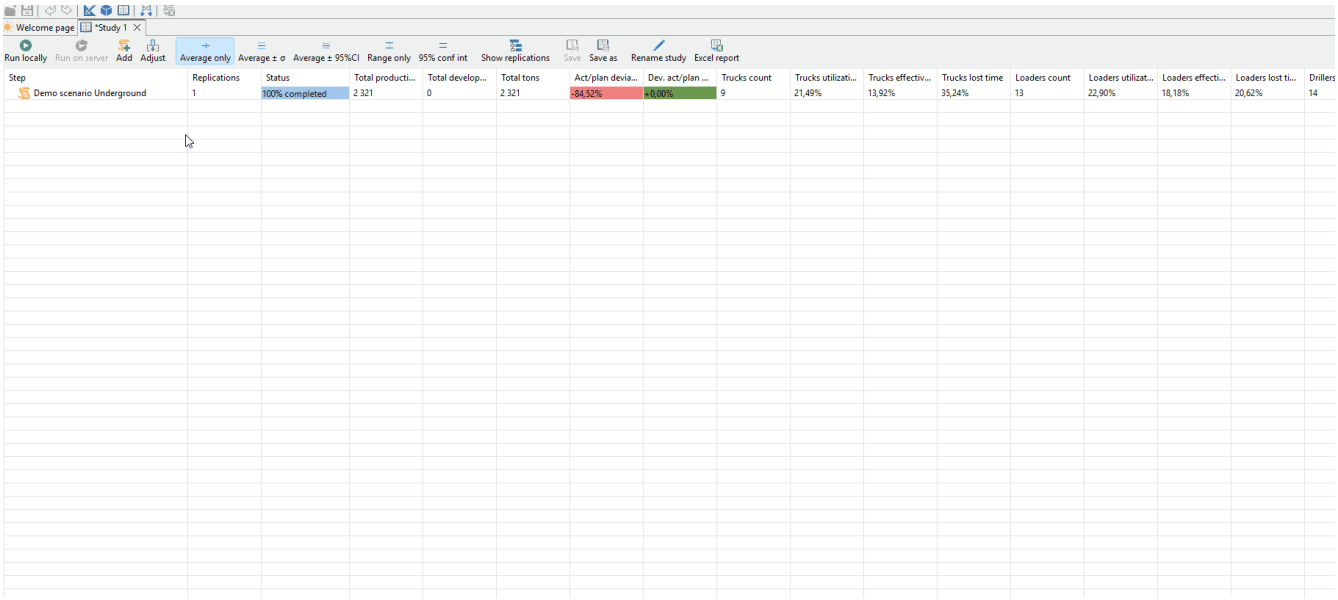
The **Constraint Analysis** mode is intended to identify scenario bottlenecks. When this analysis is run, MineTwin automatically launches the scenario simulation multiple times with available modifications applied, removing each major constraint in turn, and shows how much the mining plan fulfillment percentage would improve if that constraint did not exist: Instead of adding individual modifications, you can launch one of the automated study modes.



The **Fleet Sizing** study uses a sequential strategy to identify the minimum sufficient amount of equipment required to achieve the production target. During this study, instances of different equipment types are added or excluded step by step:



The **Equipment Units Count Variation** study allows users to configure and run one- and two-axis sensitivity analysis of a set of target KPIs against changes within a specified range in the amount of equipment and/or various operating parameters.

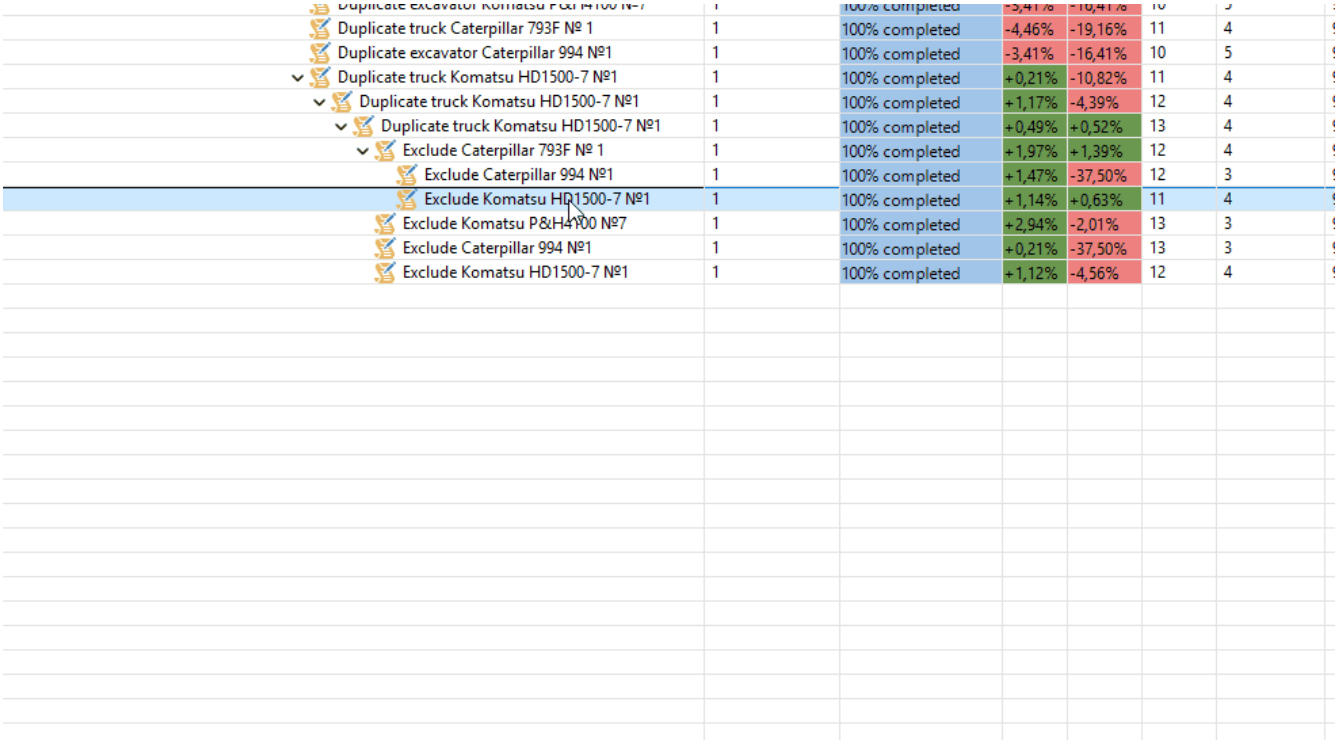


The following sections describe these modes in more detail.

Any step can be deleted through the context menu or by pressing **Delete** on the keyboard:

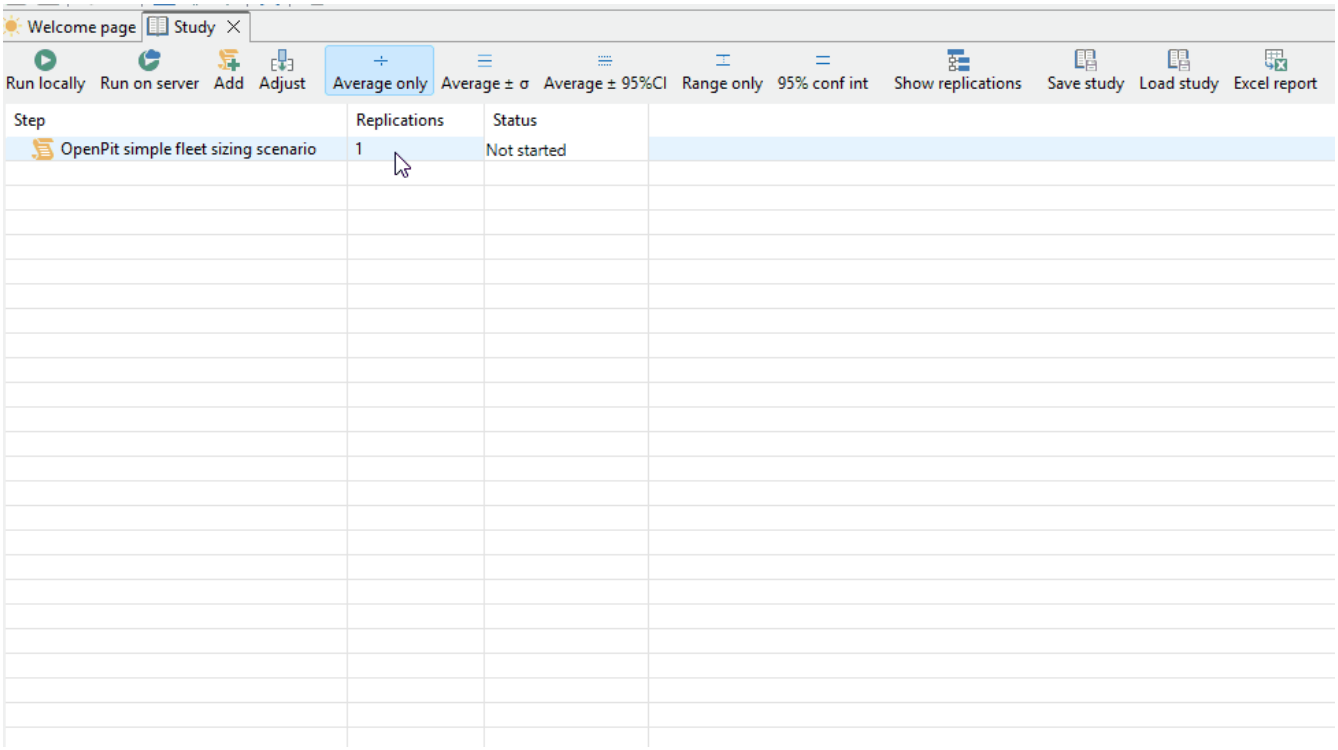
Duplicate truck Caterpillar 793F № 1	1	100% completed	-4,46%	-19,16%	11	4
Duplicate excavator Caterpillar 994 №1	1	100% completed	-3,41%	-16,41%	10	5
Duplicate truck Komatsu HD1500-7 №1	1	100% completed	+0,21%	-10,82%	11	4
Duplicate truck Komatsu HD1500-7 №1	1	100% completed	+1,17%	-4,39%	12	4
Duplicate truck Komatsu HD1500-7 №1	1	100% completed	+0,49%	+0,52%	13	4
Exclude Caterpillar 793F № 1	1	100% completed	+1,97%	+1,39%	12	4
Exclude Caterpillar 994 №1	1	100% completed	+1,47%	-37,50%	12	3
Exclude Komatsu HD1500-7 №1	1	100% completed	+1,14%	+0,63%	11	4
Exclude Caterpillar 994 №1	1	100% completed	+0,99%	-37,50%	11	3
Exclude Komatsu P&H4100 №7	1	100% completed	+2,94%	-2,01%	13	3
Exclude Caterpillar 994 №1	1	100% completed	+0,21%	-37,50%	13	3
Exclude Komatsu HD1500-7 №1	1	100% completed	+1,12%	-4,56%	12	4

Any step can also be saved as a separate scenario for later use.



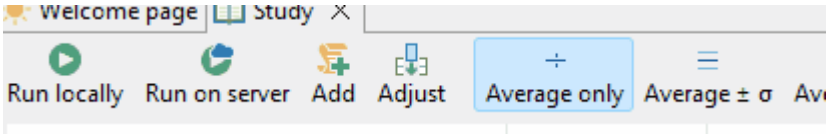
3.4. Setting the Number of Replications

1. Specify the number of replications (runs) for the selected step.
2. Each replication uses a different random number seed.
3. Enable **Show replications** to display individual run values.



3.5. Running Calculations

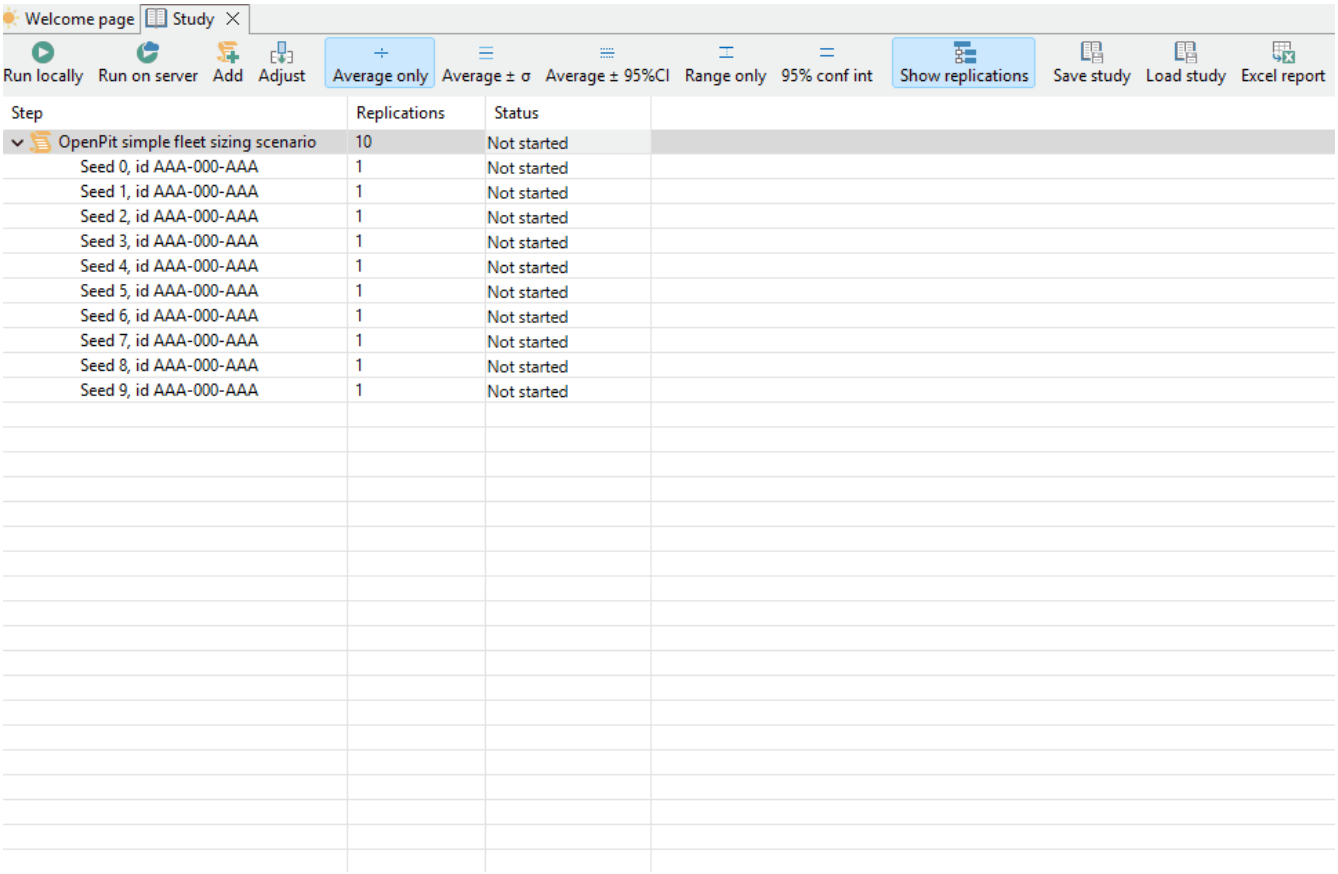
Choose how to run the calculations:



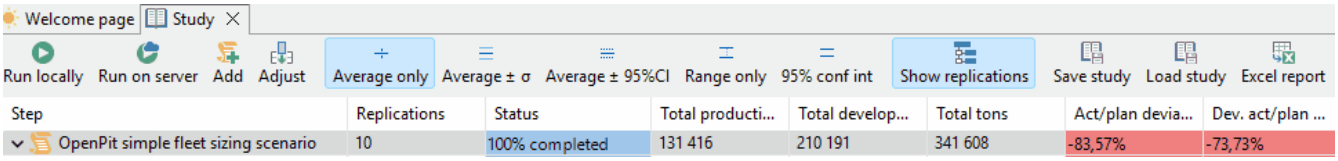
- **Run Locally** — execution on the local machine
- **Run on Server** — calculations on the MineTwin server

Server mode significantly reduces the load on the user's computer when the workload is large.

1. Click **"Run locally"** or **"Run on server"**.
2. Track the execution status in the corresponding table column.
3. You can switch to another mode (for example, scenario editing) without waiting for the calculations to finish. They will continue in the background, and the results will be available when you return.

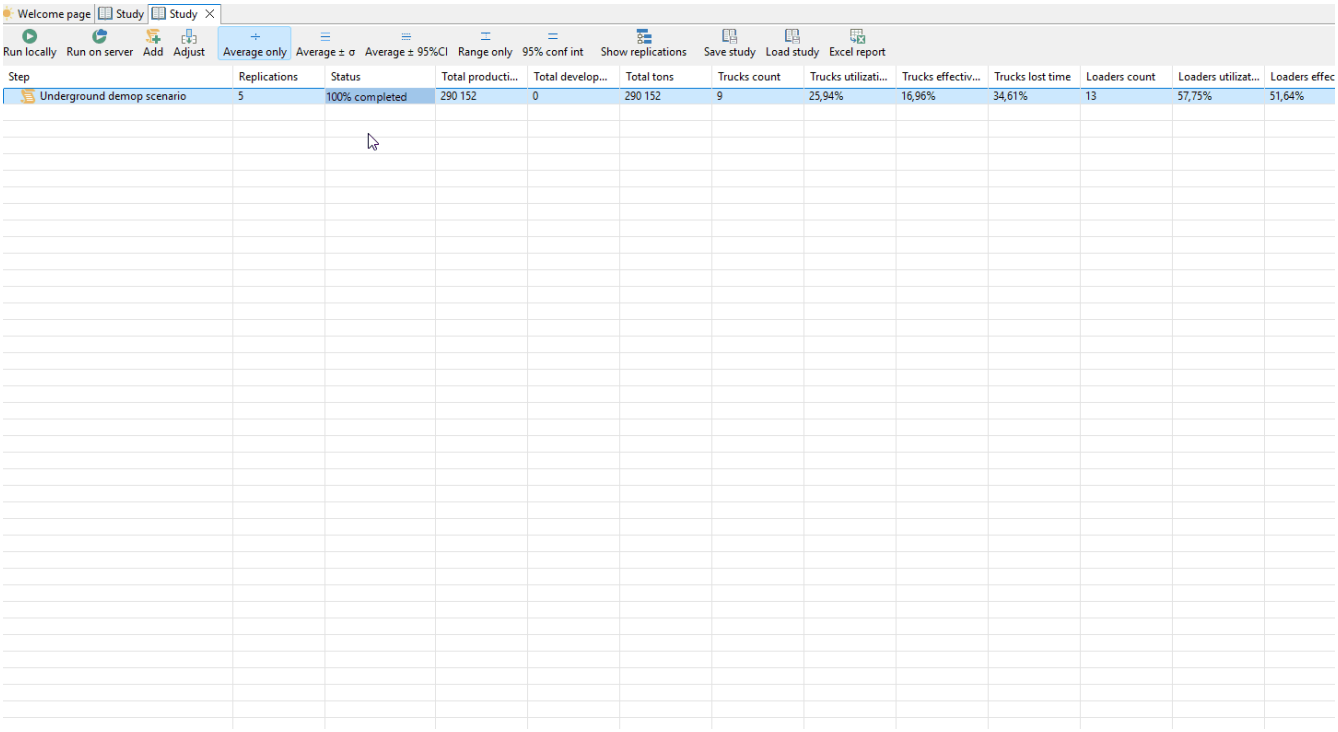


Any study can be saved and reopened later. If calculations are performed on the server, the study can be saved even before all step calculations are finished. After reopening, already calculated results will be automatically loaded from the server.



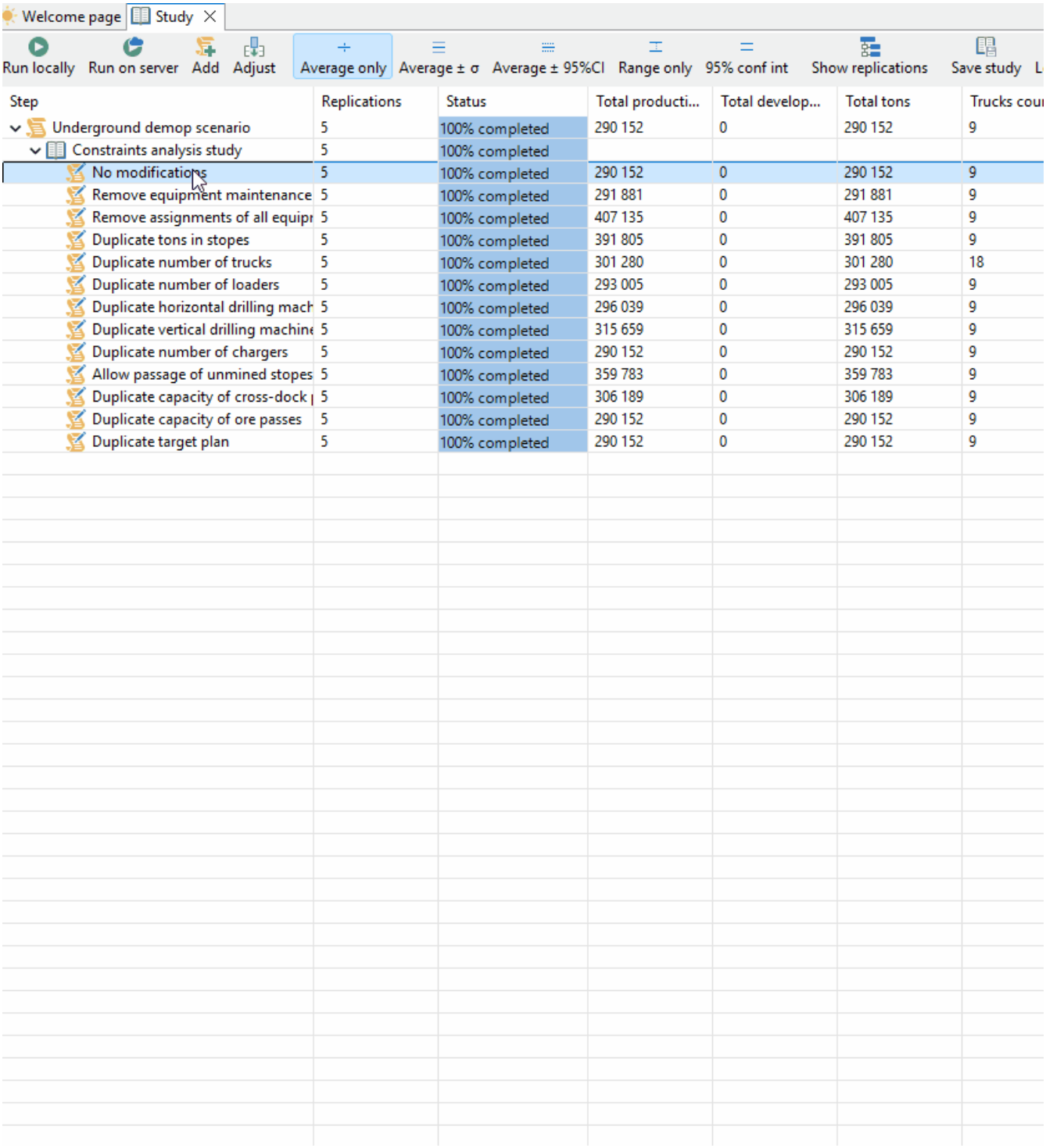
3.6. Viewing and Analyzing Results

Results appear in the study step table. To customize which data columns are displayed in the table, click the **Adjust** button on the toolbar:



Data columns, including those added via the **Adjust** button, can be dragged by their headers to change their order.

You can right-click any step and choose **Show detailed results**:

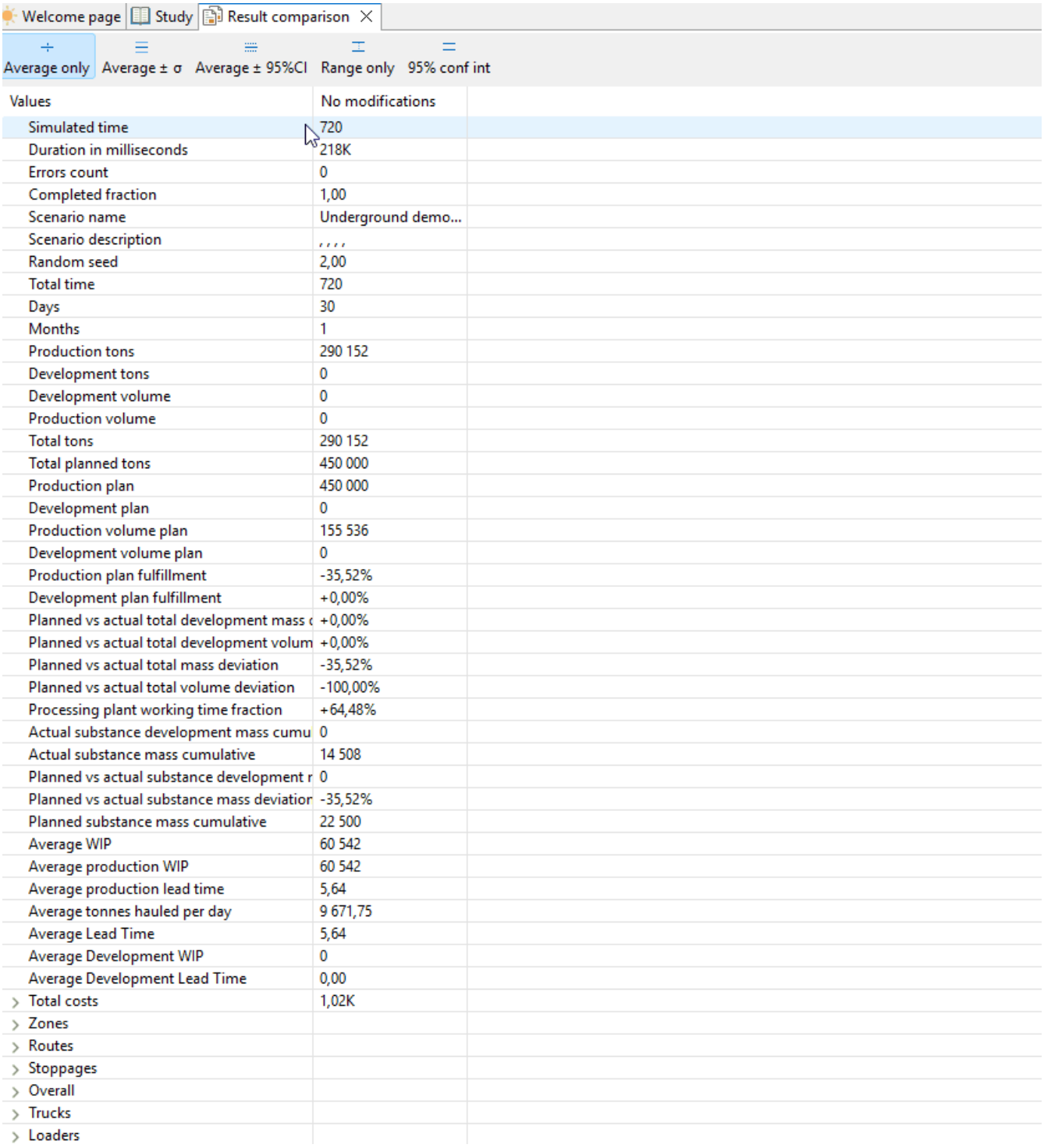


This opens the **Result comparison** tab with detailed metrics.

If a comparison tab already exists, use the command:

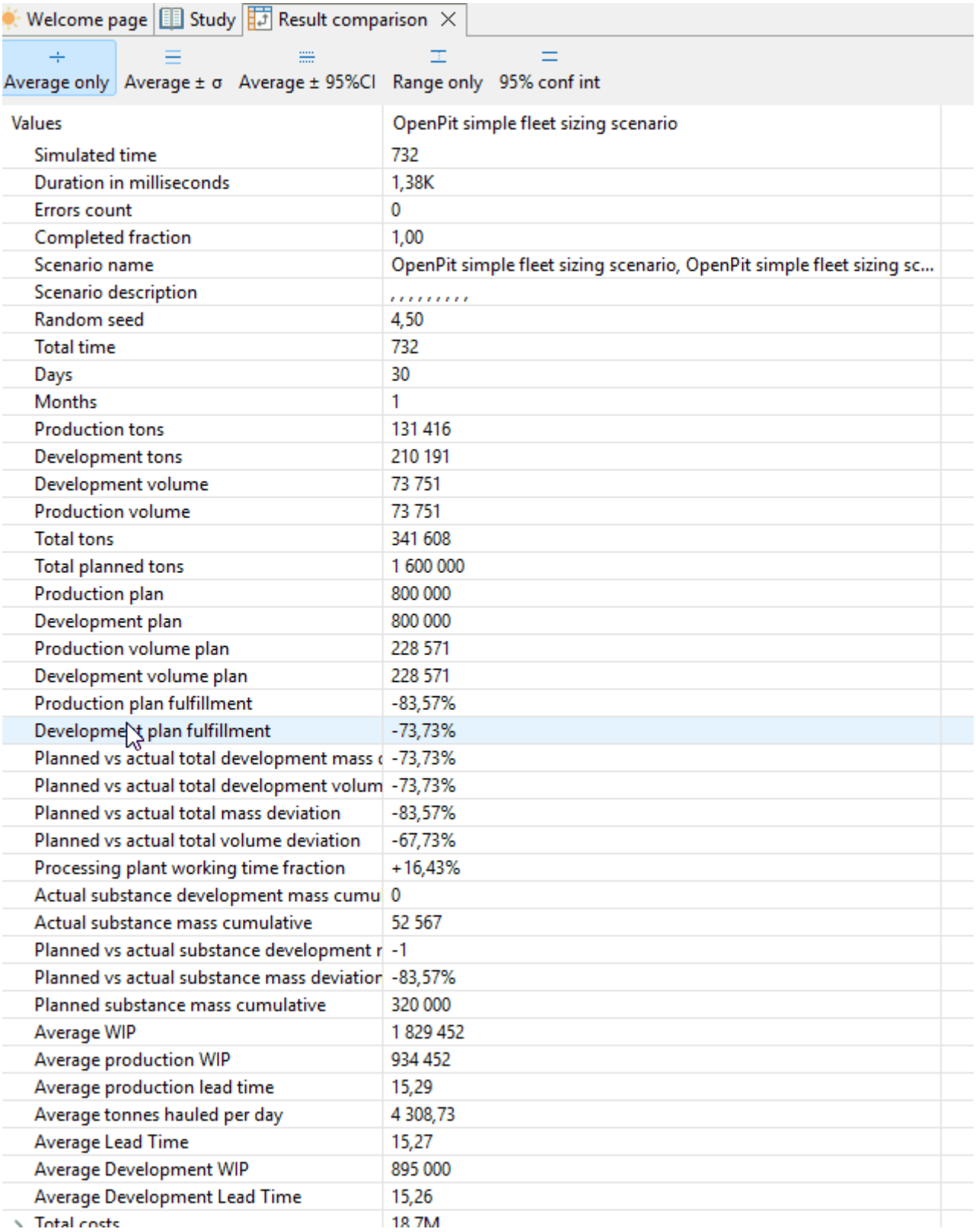
- **Add results to comparison**.

You can add other scenarios to the comparison tab and set one as a baseline. Differences will be calculated automatically:



Values	No modifications
Simulated time	720
Duration in milliseconds	218K
Errors count	0
Completed fraction	1,00
Scenario name	Underground demo...
Scenario description	, , , ,
Random seed	2,00
Total time	720
Days	30
Months	1
Production tons	290 152
Development tons	0
Development volume	0
Production volume	0
Total tons	290 152
Total planned tons	450 000
Production plan	450 000
Development plan	0
Production volume plan	155 536
Development volume plan	0
Production plan fulfillment	-35,52%
Development plan fulfillment	+0,00%
Planned vs actual total development mass (	+0,00%
Planned vs actual total development volum	+0,00%
Planned vs actual total mass deviation	-35,52%
Planned vs actual total volume deviation	-100,00%
Processing plant working time fraction	+64,48%
Actual substance development mass cumu	0
Actual substance mass cumulative	14 508
Planned vs actual substance development r	0
Planned vs actual substance mass deviatior	-35,52%
Planned substance mass cumulative	22 500
Average WIP	60 542
Average production WIP	60 542
Average production lead time	5,64
Average tonnes hauled per day	9 671,75
Average Lead Time	5,64
Average Development WIP	0
Average Development Lead Time	0,00
Total costs	1,02K
Zones	
Routes	
Stoppages	
Overall	
Trucks	
Loaders	

If your scenario contains several replications you can use the toolbar to toggle how result values are aggregated:



Values	OpenPit simple fleet sizing scenario
Simulated time	732
Duration in milliseconds	1,38K
Errors count	0
Completed fraction	1,00
Scenario name	OpenPit simple fleet sizing scenario, OpenPit simple fleet sizing sc...
Scenario description	, , , , , , , , ,
Random seed	4,50
Total time	732
Days	30
Months	1
Production tons	131 416
Development tons	210 191
Development volume	73 751
Production volume	73 751
Total tons	341 608
Total planned tons	1 600 000
Production plan	800 000
Development plan	800 000
Production volume plan	228 571
Development volume plan	228 571
Production plan fulfillment	-83,57%
Development plan fulfillment	-73,73%
Planned vs actual total development mass c	-73,73%
Planned vs actual total development volum	-73,73%
Planned vs actual total mass deviation	-83,57%
Planned vs actual total volume deviation	-67,73%
Processing plant working time fraction	+16,43%
Actual substance development mass cumu	0
Actual substance mass cumulative	52 567
Planned vs actual substance development r	-1
Planned vs actual substance mass deviation	-83,57%
Planned substance mass cumulative	320 000
Average WIP	1 829 452
Average production WIP	934 452
Average production lead time	15,29
Average tonnes hauled per day	4 308,73
Average Lead Time	15,27
Average Development WIP	895 000
Average Development Lead Time	15,26
Total costs	18,7M

Available views:

- Mean value only
- Mean ± standard deviation
- Mean ± 95% confidence interval
- Value range only
- Confidence interval bounds only

How the confidence interval works:

The confidence interval allows you to determine the range in which the true average value of a metric is likely to fall with 95% probability (confidence level), based on your sample data. The calculation uses a special statistical method called the t-distribution, which accounts for the sample size. This is particularly important when the number of observations is relatively small. The confidence interval is calculated using the following formula:

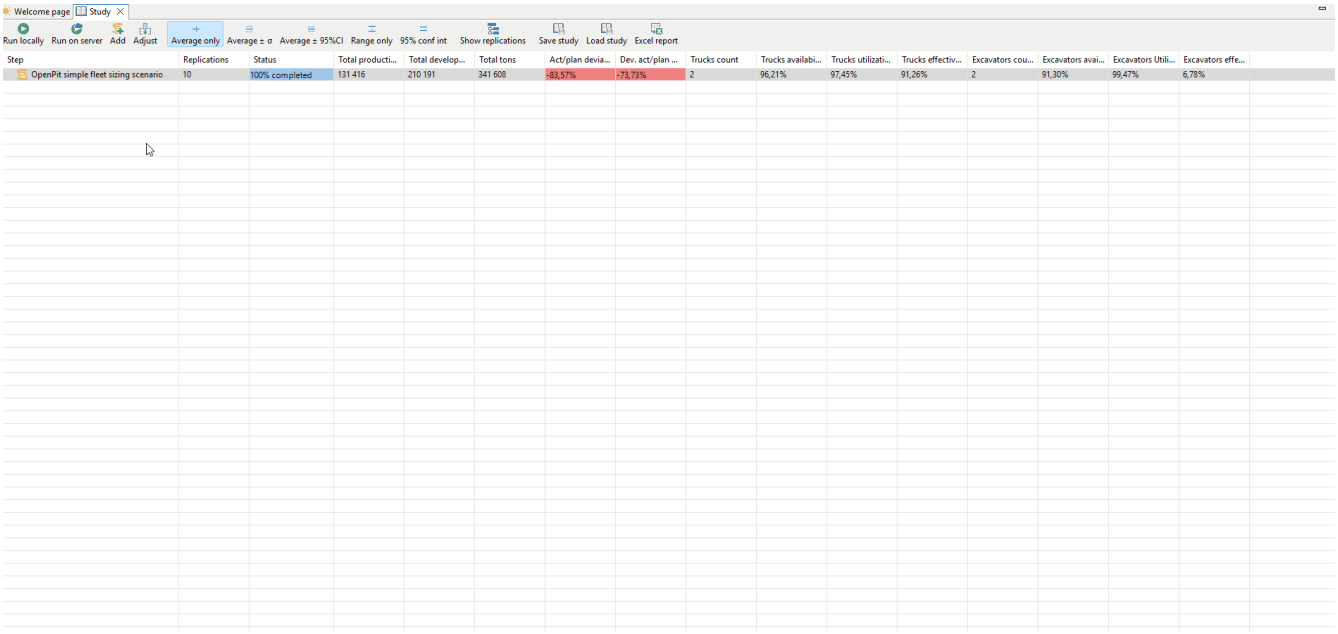
$$\text{Confidence Interval} = \left[\bar{x} - t^* \cdot \frac{s}{\sqrt{n}},\ \bar{x} + t^* \cdot \frac{s}{\sqrt{n}}\right]$$

where:

- $\bar{x}$ — the sample mean,
- s — the sample standard deviation,
- n — the number of observations,
- t^* — the critical t-value based on the confidence level and degrees of freedom.

3.7. Reports

Each step supports a **Scenario summary report**, generated from the context menu:



The report is generated as an HTML page and can be viewed in MineTwin. The report can also be opened in any browser (the **Open in Browser** button on the toolbar). This makes it possible to print it to PDF using browser tools.

Each automated study additionally generates its own report. To view it, select the corresponding item from the study context menu.

The study toolbar includes an **Excel Report** button.

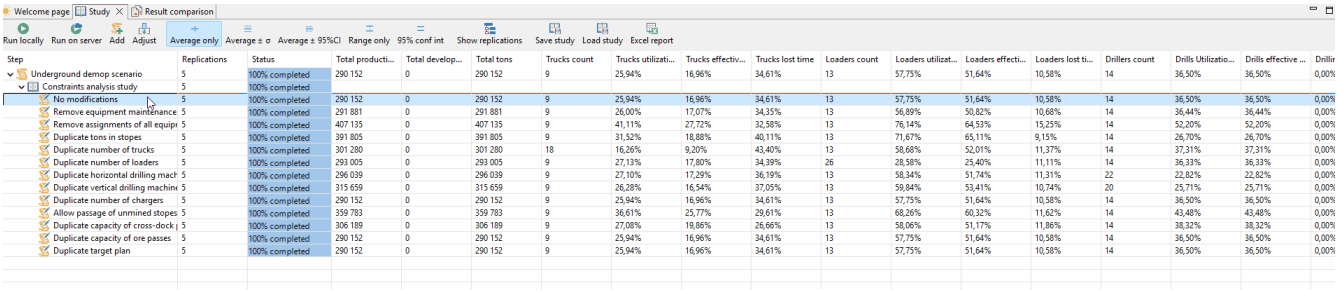
When clicked, the study table is saved to an Excel file and immediately opened in the corresponding application.

3.8. Study Examples

3.8.1. Study: Constraint Analysis

Constraint analysis mode is intended to identify scenario bottlenecks. When the analysis is run, MineTwin automatically launches the scenario simulation multiple times, removing each major constraint in turn, and shows how much the mining plan fulfillment percentage would improve if that constraint did not exist.

Each constraint is modeled through a separate modification, and the results are compared with the baseline scenario. The visual representation makes it easy to identify the most critical bottlenecks.



The following modifications are available:

- **Remove variability**;
- **Remove equipment maintenance**;
- **Remove equipment failures**;
- **Remove assignment of all equipment units to mine areas**;
- **Duplicate tons in stopes**;
- **Duplicate the number of trucks**;
- **Duplicate the number of loaders**;
- **Duplicate horizontal drilling machines**;
- **Duplicate vertical drilling machines**;
- **Duplicate the number of chargers**;
- **Allow passage of unmined stopes**;
- **Duplicate capacity of cross-dock points**;
- **Duplicate capacity of ore passes**;
- **Duplicate target plan**.

The exact set of available modifications may vary depending on the software version.

A right-click command, **Constraint Analysis Report**, opens the HTML report in a separate tab.

The report contains:

- a **Methodology** section describing the study methodology;
- a **Results** section;
- a table with the following columns:
  - **Modification**;
  - **Total production and development tons mined**;
  - **Relative difference to the baseline scenario**;
  - **Modification description**.

Such theoretical experiments help validate modeling assumptions. This **Constraint analysis** is typically the first step toward exploring real-world strategies for performance improvement. It provides a holistic view of system limitations and reveals complex interdependencies in mining operations.

3.8.2. Study: Fleet Sizing

This mode is designed to select the mobile equipment configuration minimally required to achieve the target production and development plans.

After launch:

1. the **No Modifications** scenario is calculated;
2. **equipment clusters** are identified — combinations of equipment class and type, as well as the areas to which they are assigned;
3. the first **Equipment Cluster Analysis** is performed;
4. within the cluster analysis, the following scenarios are created:
   - **Duplicating equipment units in all clusters**;
   - variations of this scenario where equipment is duplicated in all clusters except one;
5. the system determines which cluster increase gives the greatest effect;
6. calculates how many equipment units need to be added;
7. generates a new scenario with additional equipment;
8. then repeats the cluster analysis.

The cycle continues until a configuration is found that allows the plan to be fulfilled for both production and development mining.

After the plan is achieved, the stage of excluding the least utilized equipment units begins:

- after each exclusion, a new scenario is generated;
- if the plan is no longer fulfilled, that branch is discarded;
- if the plan is still fulfilled, the study continues deeper into that branch with further equipment exclusions;

- the process continues until a dead end is reached.

The entire process is displayed as a hierarchical table with branching study steps.

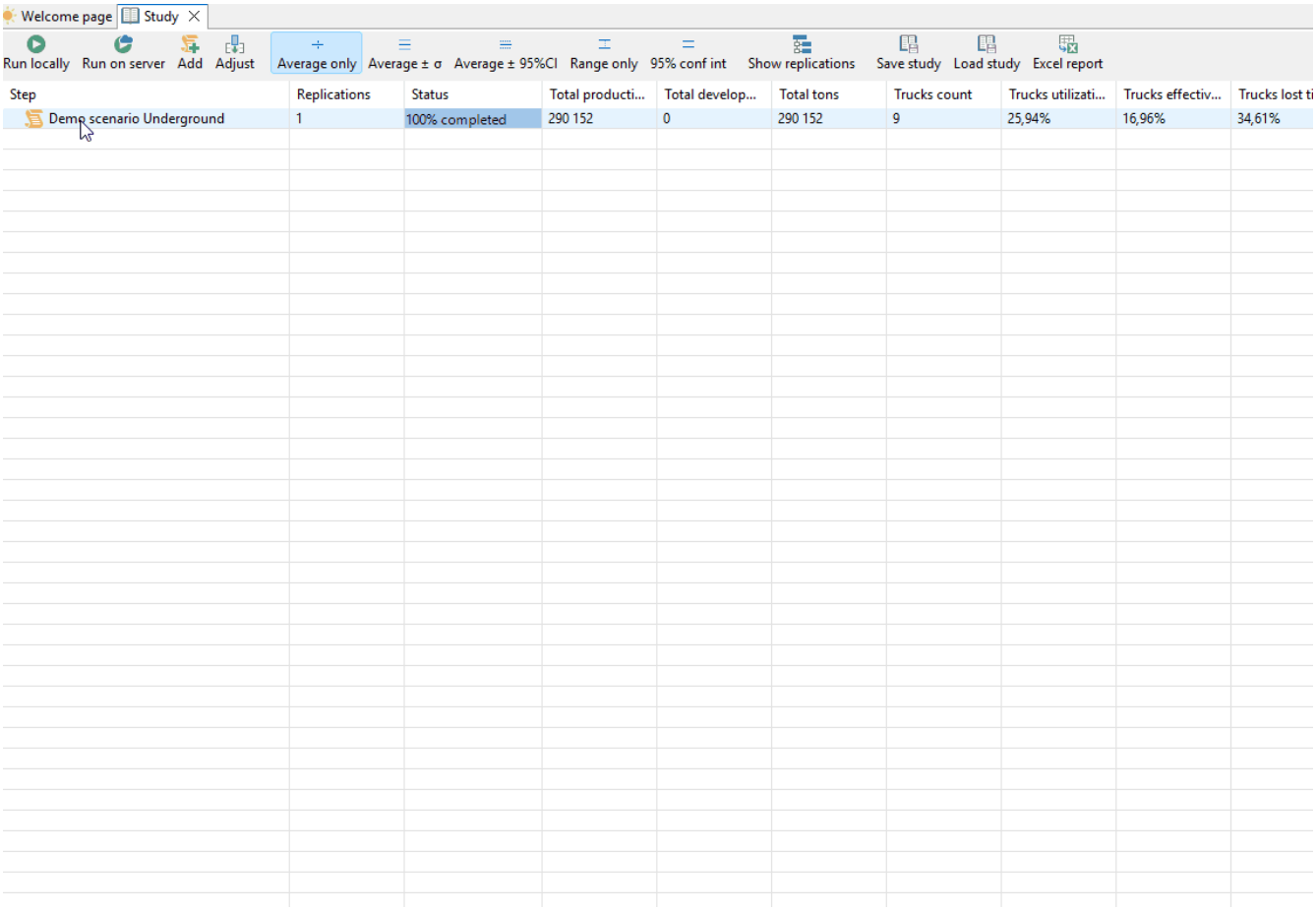
Each **Equipment Cluster Analysis** generates a separate HTML report. The report contains:

- the baseline limiting plan fulfillment;
- the theoretical maximum achieved by duplicating equipment in all clusters;
- a list of clusters;
- the number of units in each cluster;
- an estimate of absolute improvement potential;
- an estimate of improvement potential per unit;
- a final recommendation for fleet changes.

The entire study for determining the optimal fleet size also generates a separate final HTML report.

The final report contains:

- comparison of the **Baseline Scenario** and the **Best Fleet Configuration**;
- target KPI achievement status;
- **Total tonnes mined**;
- **Ore tonnes mined**;
- **Development or waste tonnes mined**;
- **Total cost**;
- **Cost per ton**;
- **Number of trucks**;
- **Number of drilling machines**;
- **Number of chargers**;
- **Number of loaders**;
- waterfall charts showing the step-by-step effect of fleet changes on total mining volume and cost per ton.



3.8.3. Study: Equipment Units Count Variation

The **Equipment Units Count Variation** mode is intended to determine how changes in equipment quantity and/or operating parameter values affect a set of target KPIs.

The mode is launched from the context menu.

After launch, a dialog box opens where the following can be specified:

- equipment to vary;
- minimum quantity;
- maximum quantity;
- variation step.

The dialog also shows how many scenarios will be generated.

After clicking **OK**, the required scenarios are created automatically. This launch creates a **one-axis study**.

Variation axes are available for different types of equipment, including:

- trucks;
- loaders;
- drills;

- charging machines; etc.

Adding a Second Variation Axis

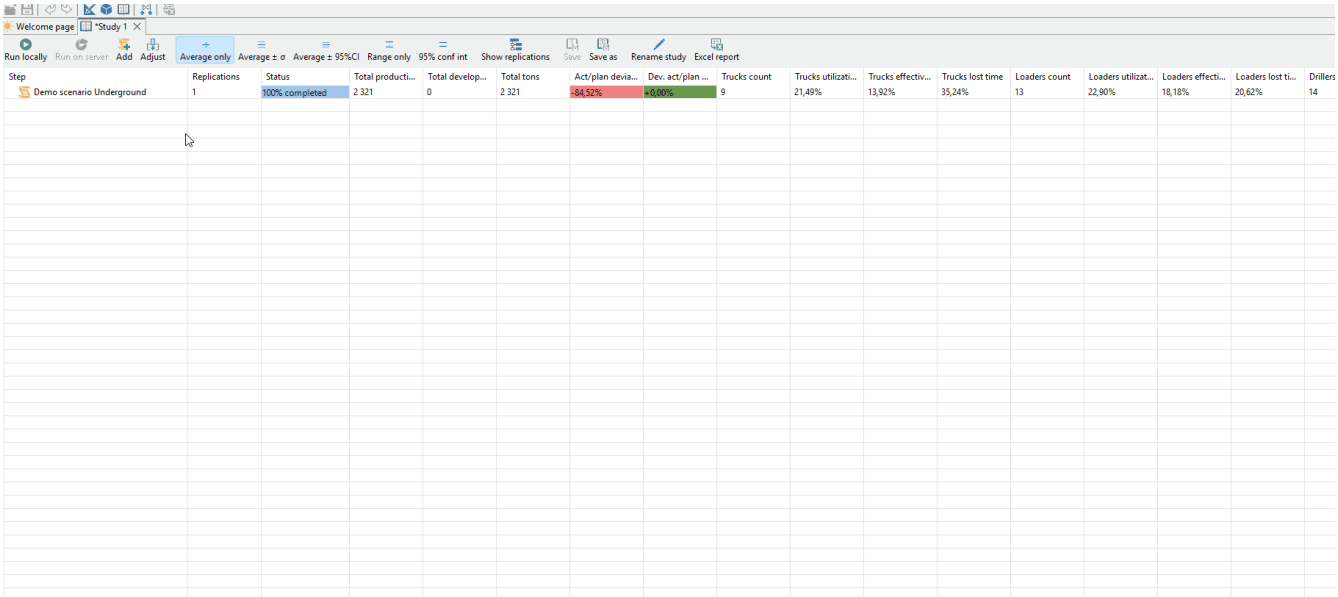
To add a second and subsequent axes for another equipment type, right-click the study and select **Add variation axis** from the context menu. A dialog box similar to the one used for the one-axis study will appear.

To add a second axis for another parameter, or to create an axis for a parameter not related to equipment quantity, you need to:

1. switch to editor mode;
2. open the tab where the required parameter is located;
3. click the book icon button to the right of the parameter;
4. in the window that opens, specify the variation range and step;
5. choose whether to apply the changes to all equipment units or only to a specific unit;
6. if necessary, enable the flag to use the parameter as the second axis;
7. select from the dropdown list the existing one-axis study to which the new axis will be added.

Thus:

- the first axis can be created via the **Study** mode as an equipment quantity study, or via the editor for varying parameter values not related to equipment quantity;
- the second axis can be added from the **Study** mode for varying equipment quantity, or from the editor through object parameters for varying its value.



Reports for Variation Studies

Different HTML reports are generated for one-axis and two-axis studies.

The one-axis report contains:

- description of the parameter under study;
- total number of experiments and replications;
- a correlation table with the following columns:
  - **Independent parameter**;
  - **Dependent KPI**;
  - **Sufficient data**;
  - **Correlation type**;
  - **Spearman correlation coefficient**;
- textual conclusions on the identified relationships;
- dependency charts for KPIs where correlation was found or its absence was confirmed.

The two-axis report contains:

- description of the two varied parameters;
- total number of experiments and replications;
- tables and visualizations in the form of a heat map showing the influence of parameters on key KPIs.

The following are analyzed in two-axis reports:

- **Impact on total tons**;
- **Impact on production tons**;
- **Impact on production plan fulfillment**;
- **Impact on limiting plan fulfillment**;
- **Impact on trucks effective utilization**;
- **Impact on drills effective utilization**;
- **Impact on chargers effective utilization**;
- **Impact on loaders effective utilization**.

3.9. Conclusion

The **Study** mode offers a powerful framework for evaluating operational strategies, identifying constraints, and making informed data-driven decisions.

By enabling structured experimentation and visual comparison of scenarios, Study mode transforms simulation into a practical decision-support tool. It helps engineers, analysts, and managers test assumptions, quantify outcomes, and prioritize actions that have the greatest operational and financial impact.

This not only accelerates the decision-making cycle but also improves confidence in strategic choices, ensuring that mine planning is based on evidence rather than intuition.

3.9.1. Summary of Key Workflows

The Study mode supports a range of structured workflows, including:

- **Creating studies** from existing scenarios
- **Adding manual or automated modifications** to explore operational changes
- **Running simulations locally or on the server**, with background execution
- **Viewing individual or aggregated results**, including statistical metrics
- **Comparing results** across different steps or scenarios using baseline mode
- **Generating reports** for each step or entire study
- **Saving any step as a reusable scenario** or continuing analysis from any step

These workflows are designed to maximize analytical flexibility while reducing manual overhead.